

**COMFORTABLE HOUSING MODEL IN NEW HOUSING PPRT
FOR ORANG ASLI**

**MODEL RUMAH SELESA DALAM PENEMPATAN BARU PPRT
UNTUK ORANG ASLI**

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COMFORTABLE HOUSING MODEL IN NEW HOUSING PPRT FOR ORANG ASLI

(keywords: existing orang asli house, government initiated, proposed comfortable)

This research investigates the proposed comfortable housing model as thermal comfort strategy in *orang asli* house in Malaysia. The Government has implemented specific development programmes for the indigenous community or the *orang asli*, which included economic and social programmes to improve their standard of living. One such special programme is called the Hard-Core Poor Development Programme (PPRT). The new PPRT house initiated by the government is not only small but has heat-trapping zinc roofs and concrete walls. This house indicated uncomfortable condition compare to the existing *orang asli* house. Unfortunately, the architectural design solutions do not permit good passive cooling for thermal comfort. This can be illustrated by the high indoor temperature experienced during the day time. In this research, Proposed Comfortable PPRT House Model has been suggested by adopting traditional *orang asli* house element and lifestyle as much as possible as alternative techniques for achieving passive cooling. The thermal comfort study in this research involved the use of computer simulation using Integrated Environment Solution (IES) technique. The specific software called Apache is used. Validation of IES Apache is done by comparing the computer simulation result with the field measurement result on existing house model. The result of the Proposed Comfortable PPRT House Model showed that the house model increased thermal comfort performance by reducing air temperature (until 2°C) and PMV index (until 1). The other important factor is that it can continuously maintain the comfortable condition in mid day regardless of the available outside climate condition. This effect is significant toward improving the thermal comfort performance of PPRT house designed for *orang asli* through passive cooling, thus provide comfortable healthy and low energy house.

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MODEL RUMAH SELESA DALAM PENEMPATAN BARU PPRT UNTUK ORANG ASLI

*(kata kunci: rumah orang asli sediaada, pengembangan khas kerajaan, ubah suai
keselesaaan terma rumah)*

Penyelidikan ini adalah untuk menilai cadangan model rumah yang selesa sebagai strategi keselesaan termal dalam rumah orang asli di Malaysia. Kerajaan telah menjalankan pengembangan khas bagi komuniti orang asli yang meliputi program ekonomi dan sosial bagi mempertingkatkan keadaan sara hidup. Salah satu program ialah Program Pembangunan Rakyat Termiskin. Reka bentuk baru rumah PPRT yang dibangunkan oleh kerajaan mempunyai kelemahan dengan adanya pancaran haba dari bumbung zink dan dinding batu bata. Reka bentuk baru rumah PPRT didapati tidak menepati keperluan keselesaan termal yang dikehendaki di dalam rumah orang asli. Malangnya juga reka bentuk senibinanya belum dapat memungkinkan pendinginan semulajadi yang baik. Keadaan ini ditunjukkan dengan tingginya suhu yang di dalam rumah pada siang hari. Ubah suai rumah PPRT telah dicadangkan dengan mengadaptasi bagian rumah tradisional orang asli dan cara hidup mereka sebagai salah satu kemungkinan di dalam teknik pendinginan semulajadi. Kajian kesesuaian termal dalam penyelidikan ini melibatkan simulasi komputer berteknik pemecahan alam secara sepadu atau Integrated Environment Solution (IES). Perisian khusus bernama Apache telah digunakan. Validasi perisian Apache telah dilakukan dengan membandingkannya dengan hasil pengukuran lapangan dan kajian dalam rumah sediaada. Keputusan ubah suai model rumah PPRT menunjukkan kesan baik kepada peningkatan prestasi kesesuaian termal dengan penurunan suhu (sampai 2°C) dan nilai PMV (sampai 1). Faktor penting yang lain ialah model ini dapat memberi dan mengekalkan keselesaan secara berterusan tanpa mengira keadaan di luar rumah. Kesan kajian ini cukup besar bagi memperbaiki prestasi keselesaan termal rumah PPRT untuk orang asli melalui penyejukan semulajadi, seterusnya keselesaan, kesihatan dan penggunaan tenaga yang rendah.

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LIST OF ABBREVIATIONS

ASHRAE	-	American Society of Heating, Refrigerating and Air Conditioning Engineers
PPRT	-	Program Pembangunan Rakyat Termiskin
PMV	-	Predicted Mean Vote
IES	-	Integrated Environment Solution
DBT	-	Dry Bulb Temperature
RH	-	Relative Humidity
IDM	-	Integrated Data Model
CUI	-	Common User Interface (CUI)
CIBSE	-	Chartered Institution of Building Services Engineers

LIST OF SYMBOLS

C	-	Celcius
d	-	Solid angle
dA	-	Surface element
dt	-	Temperature reduction
e	-	emissivity
T _{amt}	-	Annual mean air temperature of the month
T _{av}	-	Mean air temperature of the month
T _n	-	Predicted neutral temperature
T _o	-	Mean outdoor temperature for the month
v	-	Air velocity

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CHAPTER 1

INTRODUCTION

1.1 Research Background

The indigenous peoples of Malaysia, or *Orang Asli* (the Malay term for the indigenous peoples in Peninsular Malaysia), are not a homogenous group. There are three kinds of “orang asli”. They are known as “Senoi”, “Orang Melayu Asli” and “Negrito”. Those who are living in Cameron Highland are the “Senoi” and the “Negrito”. The “Senoi” looks exactly like the Malaysians. Those who are darker are the Negrito. The “Senoi” originated from the hills of Vietnam, Cambodia and Northern Thailand about 6,000 to 8,000 years ago. In Cameron highland, they work as a worker on the highland tea estate to earn money. The “Negritos” are the semi-nomadic tribes of the “Orang Asli”. The “Negritos” arrived in Malaya 8,000 years ago. Their forefathers were hunters and gatherers who used to live in cave and rock shelter. These “Orang Asli” live in the jungle in small tribes. Every tribe has their own chief. The roof of their house normally is made of leaves while the floor is made of wood. They usually live near the river for the river is their main source of water. Since they are nomad, they usually move to another place from time to time. But, they will not move to another place for no reason. They will only move to another place when something happened, such as death or severe illness. However, the chief of the tribe will decide whether to move or not and where to move to. For them, building a house only takes 2 to 3 hours. Although government built long houses for them, they still feel very much comfortable staying in the jungle. However, they are all marginalised socioeconomically and culturally. The lifestyle and means of subsistence of the indigenous peoples varies from place to place.

The Government implemented specific development programmes for the indigenous community, the Orang Asli, which included economic and social programmes that improved their standard of living. During the Seventh Malaysia Plan period (1996-2000), the focus of anti poverty programmes was directed at the hard-core poor, spearheaded by a special programme called the Hard-core Poor Development Programme (PPRT). Some of the pertinent issues include the provision of training, in terms of attitudinal change as well as the application of improved production technology and small-scale industry among agricultural households, and general education for children of poor households, especially in rural areas. The success of programmes, as allocated from the Seventh and Eighth Malaysia Plans, to alleviate poverty and provide economic opportunities has demonstrated the effectiveness of the nation's efforts to raise the standard of living of all Malaysians. In addition, specific urban-based programmes, namely squatter resettlement and low-cost housing projects, improved the living conditions of the urban poor. As for the hardcore poor, the rapid economic growth prior to mid-1997, and the intensified implementation of the Development Programme for the Hardcore Poor or Program Pembangunan Rakyat Termiskin (PPRT) helped in reducing its incidence. One effort to eradicate poverty is through housing provision. However, according to Peninsular Malaysia Orang Asli Association Selangor Branch Vice-Chairman, Yusof Alip, only 10 to 15 houses are allocated annually, per district, under the Seventh Malaysia Plan (through the Orang Asli Department). This means that, "less than 5% of the Orang Asli population receive houses each year." (*The Star* 17 October 1996). Nonetheless, the suitability of the houses is questionable. For example, Mahmud Kema from Kampung Bukit Kecil was given a two-room house measuring 4.8 x 5.4m as part of a poverty eradication programme. The house is not only small but has heat-trapping zinc roofs and concrete walls. So, the Government Initiated PPRT house indicated unfomfortbale condition compare than the existing orang asli house. Fanger (1970) defined thermal comfort for a person as a condition of mind, which expresses satisfaction with thermal environment. Thermal comfort is affected by two main factors (Fanger, 1970; Abdul Razak, 2004): first, environmental factor (air temperature, relative humidity, air movement, and radiation; second, subjective factor (activity, clothing, age, sex, heath condition, food and drink, skin color, human size. However, these study only investigate the thermal comfort condition in orang asli house.

1.2 The Problem Statement

The main challenge confronting indigenous peoples today is that of being dispossessed of their native customary land. Land is their source of livelihood and its dispossession has invariably trapped indigenous peoples into a cycle of poverty. Equally important is the fact that land embodies their cultural identity and thus its loss strikes at the very core of their identity. The irony is that it is the "*modern*" development strategies that have resulted in the present environmental crisis. There is international level agreement that development has to be sustainable, i.e. consideration has to be given to the environment in planning. Research has found that the traditional lifestyles of indigenous peoples are environmentally sound. This implies that we may in fact have a great deal to learn from them. This needs to be questioned on several grounds. First, what the environmental house condition do indigenous peoples want? Secondly, will indigenous peoples feel comfortable with the new housing development proposed?

1.3 Research Hypothesis

The hypothesis of this study is that "appropriate" design of PPRT house model for orang asli will achieve the following:

- Decrease temperature inside house or similar with outdoor climate condition.
- Provide optimum PMV within the range of the thermal comfort requirement (0 until 0.5) for prediction of the effectiveness of the comfortable house.
-

The term "appropriate" refers to the best performance of house model which will achieve lower the air temperature and PMV index inside the house in order to obtain comfortable house.

1.4 Research Questions

The following questions will be addressed in this study:

- Q1. Is the Government Initiated PPRT house model comfortable in Malaysian climatic condition?
- Q2. Is the existing orang asli house model comfortable in Malaysian climatic condition?
- Q3. What is the design idea required for the proposed comfortable PPRT house model to obtain better thermal comfort condition in Malaysia in relation with climate condition elements?
- Q4. Does the proposed comfortable PPRT house at (Q3) effective to increase thermal comfort condition in orang asli house?
- Q5. What is the limitation of the proposed comfortable PPRT house model towards increasing comfortable house?

1.5 Research Objective

The main objective of this study is to assess and compare the comfortable housing model in PPRT housing for orang asli.

Other specific objectives of the study are as follows:

- To evaluate thermal comfort performance in PPRT house
- To develop thermal comfort design for PPRT house

1.6 Scope and Limitations

The scope of this study is to evaluate the thermal comfort condition of existing orang asli house, government initiated PPRT and proposed comfortable PPRT house model for Malaysia's orang asli. The indoor thermal comfort aspects are major issue. There are other parameters effecting thermal comfort, for e.g. air

temperature, humidity, air velocity, clothing, metabolic heat production and so forth (Givoni, 1981; Abdul Razak, 2004). Metabolic rate and clothing are assumed that by setting the occupant at recommended set value, it will provide the required thermal quality for that space. This study is entirely carried out by using computer simulation program IES (Version 5.6) and thus bears the limitations of the simulation tool used.

1.7 Importance of the Research

The out come of this study is expected to show that the effectiveness of the PPRT house model design will provide decrease indoor temperature and the PMV index for comfortable house. Hence, findings of this study will enable and provide the building designer with wider range of options in selecting appropriate thermal comfort strategy for achieving comfortable PPRT house.

1.8 Organization of this Research Report

The study is divided into five chapters as summarized below.

Chapter one introduces the main issue of this research. This chapter discusses the research background, problem statements, hypothesis of the study, research questions, objective, scope and limitations of the study, importance of the research and the overall structure of the study are also presented in this chapter.

Chapter two presents the literature review on climate condition and thermal comfort study for Malaysia. All aspects of thermal comfort study are discussed in this chapter with the intention of giving a comprehensive review of the comfort condition.

Chapter three discusses the research design and the methodology implemented in the thermal comfort study. The justification of selecting the methodology for this study is also elaborated. Further, the development of the base model, procedures, assumptions, limitations, condition and the overall setting-up of the IES simulation are also described. The reliability and validity of the methods and simulation procedures are also discussed. The estimation of the temperature and PMV index for the research is also presented. Finally, the data analysis criteria are discussed, which is used to analyze the results of the experiment.

Chapter four presents the results and analysis of the existing orang asli house, government initiated PPRT house and proposed comfortable PPRT house model. The principle findings of the experiment and simulation are also summarized. The results of the research are analyzed as follows by:

- Assessing the original or existing orang asli house model of IES simulation of thermal comfort within Malaysia's climate.
- Assessing the Government Initiated PPRT house model on the targeted effectiveness indoor temperature and PMV index for thermal comfort performance.
- Assessing the performance of proposed comfortable PPRT house model on Malaysian climate condition.
- Assessing the comparison of PPRT model on selected climate condition.

This chapter in general is also divided into two sections. Section one discusses the IES simulation of the original or existing orang asli house, government initiated PPRT house and proposed comfortable PPRT house on the comfort condition. The neutral temperature, PMV, comfort index and impact of house orientation are also discussed in order to understand the basic thermal comfort condition within monthly climate conditions. Section two discusses the comparison of PPRT house model employed onto the selected climate condition. The results obtained from the simulation exercises are presented and analyzed. This includes comparative analysis of the predicted internal temperature and PMV index obtained from the PPRT model with the required thermal comfort value in Malaysian climate. The summary of the major findings is also presented in this chapter.

Chapter five concludes the study by summarizing the major findings of the experiment. It also outlines the suggestions for future research on thermal comfort study especially beyond the limitations of this study.

CHAPTER 2

LITERATURE REVIEW

2.1 Malaysia's Climate Condition

Malaysia lies between 1° and 7° North latitudes and 100° and 120° East longitudes. Malaysia has two main land areas which is the Peninsular Malaysia and East Malaysia. Being very close to the equator, Malaysia naturally experiences an equatorial climate which is characterized by hot and humid condition and heavy rainfall throughout the year with no distinct dry season. Malaysia also enjoys abundant sunshine all year round and experiences an almost constant temperature with a yearly mean of between 26°C and 27°C. The mean maximum daytime temperature is between 29°C to 32°C while the mean minimum temperature is between 22°C to 24°C at night in the coastal areas. Because it is surrounded by the sea and receives heavy rainfall throughout the year with an annual average of about 2000mm to 3500mm, its high humidity and heavy cloud cover causes a low yearly diurnal temperature of about 2°C. Daily diurnal temperature is higher, i.e. between 5°C to 12°C (Samirah, 1998). Malaysia falls under the influence of the Southwest Monsoon and the Northeast Monsoon. The Southwest Monsoon originates from Australia and blows across the Sumatera Island and the Straits of Malacca in the months of May to September. During Southwest Monsoon season, the West coast of Malaysia and Sabah and South of Sarawak receive heavy rainfall. The Northeast Monsoon originates from the central Asian continent and blow across the South China Sea through Malaysia to Australia from the months of November to March (Majid, 1996). All area in Malaysia that faces and exposes to the South China Sea not only receive heavy rainfall during these months but also receive the strongest

winds. Thus the monsoons will bring about more intense rainfall. Generally, Malaysia experiences light winds of variable speed with the minimum wind speeds occurring just before dawn and the maximum, in the afternoon. This pattern is controlled by convection in the surface boundary layer as the sun heats the ground during the day and is cooled by radiation during the night (Exell, .R.H.B. and Fook, C.T. 1985)

2.1.1 The Wind Climate of Malaysia

It is essential to know the geographical conditions of Malaysia in order to understand its wind climate. Malaysia is made up of two major sectors: the Peninsula and the eastern sectors (Sarawak and Sabah) in the northern part of the island of Borneo. The Peninsula is bounded by Thailand in the north, separated from the island of Sumatra by the Malacca Street along its western coast, detached from the small island of Singapore by the Tebrau Straitt in the south, and separated from the eastern sectors by the South China Sea in the east. Peninsular Malaysia, experiences a hot-humid tropical climate with no distinct seasonal variation (Yeang, 1992). The peninsula is narrow and divided into two flat coastal plains by the central mountain ranges. The primary and secondary forest that covers almost three quarters of the land area is important in modifying the climate near the ground by absorbing heat, moderating temperature, giving shade and modifying the wind climate (Yeang, 1992). At macro scale, peninsular Malaysia and the other parts of Southeast Asia are influenced by the major air streams that originate from the North-east and Central Asia, the North Pacific, Australia, the South Indian Ocean and the South Pacific (Takashi, 1993). The air streams pass over Southeast Asia in three main directions and form boundaries. The three boundaries are (as suggested by Majid, 1996):

- a) The Northern Equatorial Airstream boundary.
- b) The Southern Equatorial Airstream boundary
- c) The Combined Airstream boundary

The winds that blow over peninsular Malaysia and other parts of Southeast Asia are related to the above three airstreams and are normally associated with the rainfall in

this area (Thomson, 1980). The patterns of air flow created by the airstreams divide the year into three seasons:

- a) The north-east Monsoon.
- b) The south-west Monsoon.
- c) The transitional periods between the monsoons.

Table 2.1: Summary of wind flow over peninsular Malaysia (Majid, 1996)

Duration	Types Of Wind	Affected Area
November December January February March	north-east Monsoon (Strong, together with heavy rain)	<ul style="list-style-type: none"> • The whole of peninsular • East coast of peninsular
April May	Transitional period (Weak and variable)	<ul style="list-style-type: none"> • The whole of peninsular
June July August September October	south-west monsoon (Not as strong as the north-east) Southerly wind (Light wind)	<ul style="list-style-type: none"> • Northern part of peninsular • Southern part of peninsular below latitude 5°N
October November	Transitional period (Weak and variables)	<ul style="list-style-type: none"> • The whole of peninsular

Table 2.1 shows that in the month of November or early December until around March, the strong north-east monsoon arrives in the peninsular with heavy rain especially on the east coast. This is followed in the month of April or May by a transitional period of between half a month and two months with weak and variable winds. In the months of June to September or early October a less strong south-west wind blows over the northern part of the peninsular. However, at about the same time the southern part of the peninsular, especially below latitude 5°N, experiences a light southerly wind. The southwest and southerly winds are never strong and are sometimes overshadow by the land and sea breezes. Finally, in the months of October and early November there is another transitional period of weak and variable wind.

Other important wind phenomena in peninsular Malaysia, especially in the coastal regions, are the land and sea breezes. These winds are developed by the differential heating and cooling over land and sea. The sea breeze begins at about 10

am and blows with the greatest force in the early afternoon and fades out at sunset (Mcliveen, 1992), while the land breeze normally takes over in the late evening and night. The land breeze is never as strong as the sea breeze and is only felt within a range of about 16 km from the shore (Yeang, 1992). However, both of these breezes can reach a maximum average speed of about 3 m/s and are able to overshadow the monsoons in some areas. The prevailing north-easterly winds are too strong to let the land breeze develop along the east coast and the sea breeze along the west coast. Since the south-west monsoons are not as strong as those from the northeast, a reversal situation may also occur, but only for a limited period.

On the whole, the surface winds over peninsular Malaysia are generally mild, with a maximum speed of about 8 m/s and gust speeds of less than 13 m/s (Majid, 1996). The percentage of calm period (periods of no wind) ranges between 20% and 50%, and varies from place to place (Mcliveen, 1992). Local squalls occur, caused by the differences in local topography that disrupt the smooth flow of air streams. Line squalls may accompany a moving air stream and intensify the wind. Both squalls are normally very active from May to August, but may vary from place to place. The most well known line squalls, which normally occur along the west coast of the peninsular, are the "Sumatras" (Majid, 1996).

A comparison between the IES monthly data and the Subang Meteorological Station monthly data (2000-2003) indicated that the IES monthly data had a range between 0.1 m/s to 0.3 m/s differences for wind speed on other months than the monthly data. Values on wind speed deviation suggests that the respective day values under predicts (February, May, August, December) and over predicts (January, March, April and November) than the monthly data, while on the values over than 15 %. However, in other months, the deviation values for wind speed ranged below 10% which is within the acceptable range. In view of the above accuracy criterion, it is assumed that the IES wind climate data provide relatively similar climatic conditions of Subang Meteorological Station data.

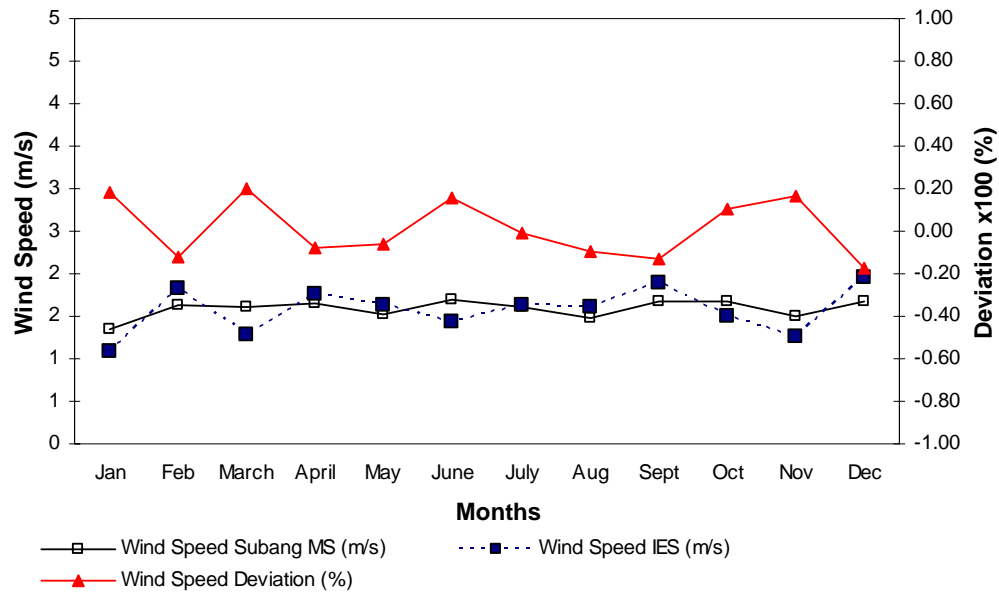


Figure 2.1: Comparison of the monthly data between IES Kuala Lumpur and Subang Meteorological Station weather file data (2000-2003) for wind speed (Latitude: 3.12° , Longitude: $+101.55^{\circ}$ & Time zone: $+7$)

2.1.2 The Solar Radiation in Malaysian Condition

In order to understand the solar radiation distribution, the geographical features of Peninsular Malaysia is briefly described. The land mass is divided into the east and west coasts by the main range running from north to south. The South-west monsoon brings rain and cloud to the west coast from June to early October, while the North-east monsoon brings rain and cloud to the east coast from November to early March. Therefore, the west coast is dry from November to April, while the east coast is dry from March to August. During the dry season, the climate is hot and sunny, with intermittent breaks of cloud formation and hence rainfall in the late afternoons due to convection current. For the purpose of this study, the peninsula will be divided into three regions according to their geographical conditions, namely, Northern Region, East Coast Region and the Southern Region. Alor Setar, Penang, Ipoh, Cameron Highlands, Sitiawan will be referred to as northern towns. Kota Bharu, Kuala Trengganu and Kuantan will be called the east coast towns, while Kuala Lumpur, Malacca, Mersing and Senai, the southern towns (Chuah, 1984).

In Peninsular Malaysia, daily total radiation data are recorded for at least five years since 1975 in three major towns, namely, Kuala Lumpur, Penang and Kota Bharu. These locations represent the three regions of different geographical and climatic conditions. Total radiation data are also recorded in stations in Ipoh, Malacca, Kuala Trengganu (since 1977) and Kuantan (since 1980). Records of radiation data in other towns are scarce. In Sabah and Sarawak the only radiation data available are those from the Kunak estate (Cuah, 1984). The solar radiation received on the ground in most parts of the peninsular is mainly the diffuse radiation component rather than direct radiation. This situation is caused by the continuous presence of clouds in the atmosphere that reflect and scatter the solar radiation. Therefore, the radiation that reaches the ground is normally much diffused, which causes the uncomfortable sky glare. The continuous presence of cloud and water vapour in the atmosphere over peninsular Malaysia also reduces outgoing radiation at night. The mean global radiation in most areas is between 10.5 to 19.0 MJ/m/day (Majid, 1996). Figure 2.2 shows the results of total monthly global solar radiation for data measured at the IES Kuala Lumpur weather data and Subang Meteorological Station (2000-2003). Comparison between the IES weather data with Subang weather data indicates same pattern for solar radiation. The IES data had a maximum of 12 % deviation for total global solar radiation on the month of May and no differences on the month of January and a mean deviation 3%. It is assumed that the IES data provide relatively similar climatic conditions of monthly data.

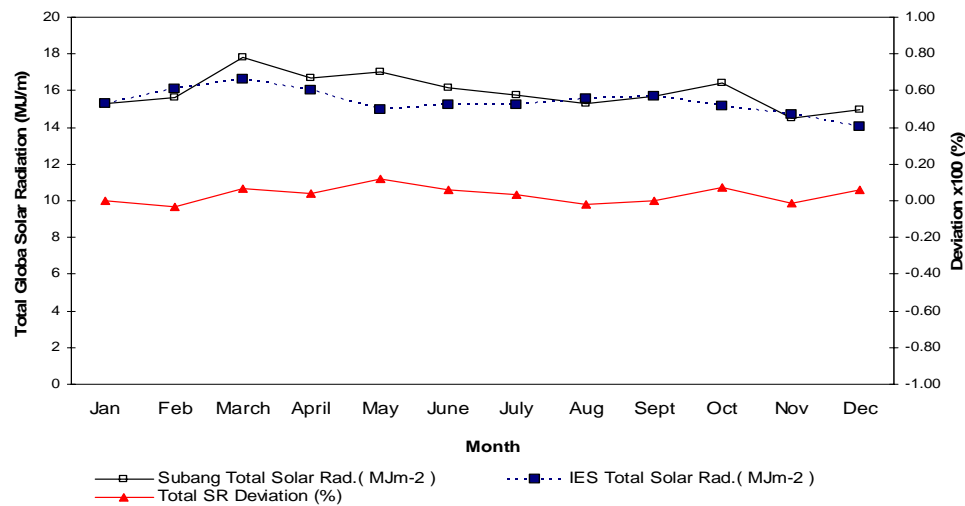


Figure 2.2: Comparison of the monthly data between IES Kuala Lumpur and Subang Meteorological Station weather file data (2000-2003) for total global solar radiation (Latitude: 3.12° Longitude: $+101.55^{\circ}$ & Time zone: $+7$)

2.1.3 Air Temperature and Relative Humidity of Malaysia

The air temperature of peninsular Malaysia remains almost uniformly high throughout the year. Based on the records monitored by the Malaysian Meteorological Service up to 1993, the daily variation of air temperature for most of the months in a year for the major parts of the low land areas is from 22°C to 34°C. The mean maximum temperature during the day is between 31°C and 34°C, and the night mean minimum varies between 22°C and 27°C (Majid, 1996). However, there is a small but noticeable drop in the monthly mean temperatures in the east coast part of the peninsular during the north-east monsoon season. In most parts of the peninsular, the mean annual range is very small and the diurnal range of the temperature is quite narrow, which is typical for a hot-humid tropical climate.

The average relative humidity (RH) remains high at about 80% in most areas in peninsular Malaysia. The actual values however may vary from 55% to almost 99%. The characteristic features of peninsular Malaysia, i.e. the steady high temperature and relative humidity, are far from being optimal for physical comfort. It is therefore the air movement from the prevailing winds, and the local land and sea breezes that are the only means of bringing some natural relief to the uncomfortable conditions of this climate (Majid, 1996).

Based on the IES Kuala Lumpur weather data, the mean temperature ranges from 25.3°C to 27.3°C. The mean relative humidity is almost uniformly high at about 76.9% to 88.9% and is similar to that of the year. A comparison between the IES data and the Subang Meteorological Station weather file data (2000-2003) indicated that the IES data had a maximum of 1.17 °C differences for dry bulb temperature on the month of May and 6.62% differences for RH on the month of July and a mean deviation 2% for DBT and 4% deviation for RH. In view of the above accuracy criterion, it is assumed that the IES weather data provide relatively similar climatic conditions of Subang Meteorological Station weather file data (2000-2003).

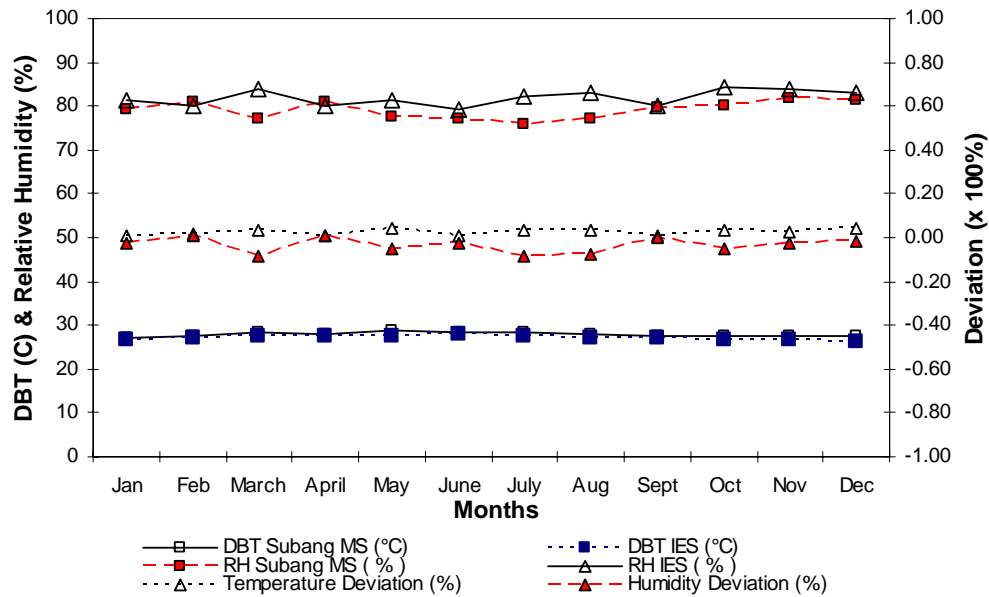


Figure 2.3 : Comparison of the IES Kuala Lumpur weather data with Subang Meteorological Station weather file data (2000-2003) for dry bulb temperature and relative humidity (Latitude: 3.12° Longitude: $+101.55^{\circ}$ & Time zone: $+7$)

Figure 2.4 show the hourly air temperature obtained by each part of monthly peak days. 6 July indicated the highest air temperature, while the maximum amount was reported at 17:00 noon. Generally, the maximum air temperature mean value was about 34°C at 13:00 – 15:00 noon. The minimum air temperature mean value was 23.9°C at 00:00 – 07:00 morning.

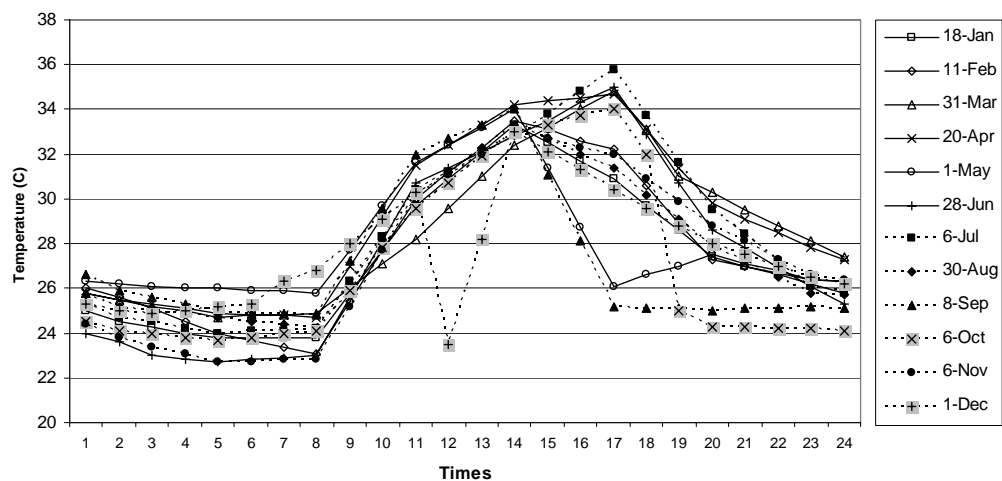


Figure 2.4: Hourly dry bulb temperature on the monthly peak day

Hourly the monthly peak day relative humidity was obtained in RH scale (figure 2.5). The highest humidity in RH (99%) was recorded on 29 June and in lowest RH (44%) was recorded on 20 April. The relative humidity had an average maximum value of about 94.67% at 00:00 – 08:00 morning. During this time, the evaporation was highest from the ground. The average minimum RH was indicated at 11:00 morning until 16:00 noon, the average value was about 52%.

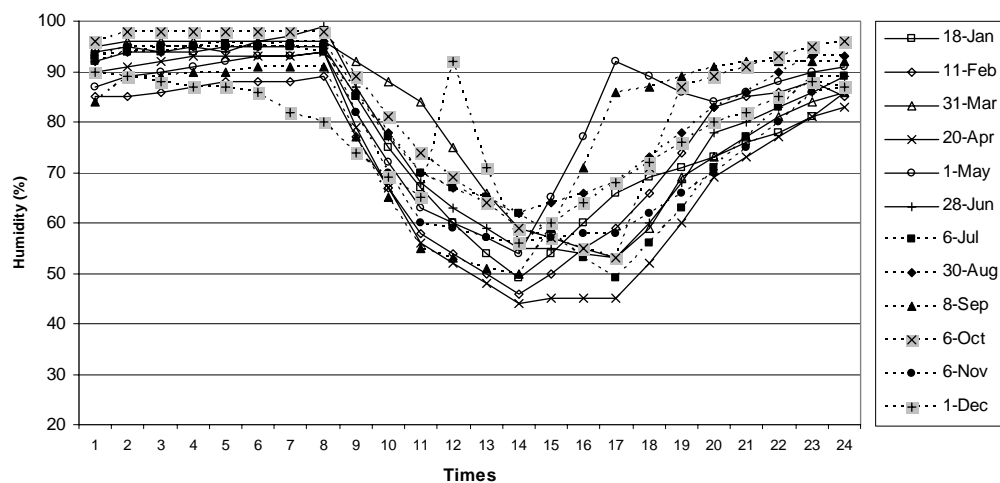


Figure 2.5: Hourly relative humidity on the monthly peak day

2.1.4 Climate Data for Comfort Analysis

Climatic data collected in meteorological stations, and published in summary form usually consists of (La Roche, 2004);

- Temperature: dry-bulb temperature.
- Humidity: expressed as relative humidity or absolute humidity. Wet-bulb or dew-point temperatures may be stated, from which the relative humidity can be determined,
- Air movement: wind speed and direction.
- Precipitation: the total amount of rain, hail, snow or dew, in mm per unit time (day, month, year).

- Cloud cover: based on visual observation and expressed as a fraction of the sky hemisphere (tenths, or 'octas' = eights) covered by clouds.
- Sunshine duration: the period of clear sunshine (when a sharp shadow is cast), measured by a sunshine recorder which burns a trace on a paper strip, expressed as hours per day or month.
- Solar radiation: measured by a pyranometer, on an unobstructed horizontal surface, usually recorded as the continuously varying irradiance (W/m^2).

The four environmental variables directly affecting thermal comfort are temperature, humidity, solar radiation and air movement. Rainfall data is helpful in designing drainage systems and slopes. These are the climatic characteristics which are most important in building design. The following data is of interest for each one of them:

- Temperature: monthly mean of daily maximal ($^{\circ}\text{C}$) monthly mean of daily minimal ($^{\circ}\text{C}$)
- Humidity: minimum mean relative humidity (early morning) (in %)
maximum mean relative humidity (early afternoon) (in %)
- Solar radiation: monthly mean daily total (in MJ/m^2 or Wh/m^2)
- Wind: prevailing wind speed (m/s) and direction

In architectural design, climate graphs and charts are useful because they permit us to understand climate quickly. Much more detailed data may be required if thermal and energy simulation programs are used. The raw weather data from the meteorological station are usually analyzed and presented in tabular form and/or in graph form.

Some design handbooks and standards such as ASHRAE also provide general climatic data for building design and manual load calculations. To study year round building performance, annual weather data will be required. The development of detailed computerized simulation programs for the thermal response of buildings has determined the need to generate a coherent set of data sets to represent hourly yearly data. Most data set systems construct a composite year's data by selecting periods from actual data over many years of recording. The specific microclimate of the site is also very important. Precipitation, terrain, vegetation, degree of solar exposure, wind patterns, the presence of water bodies, geology and the influences of buildings or other built forms on or near the site create unique, site-specific, climatic conditions (Crowther R., 1984). Since this microclimate might considerably affect conditions close to the building and its design, the architect must also try to determine its effects in thermal performance of the building either by collecting data

through low cost weather stations or by trying to determine the microclimatic effects on available data (La Roche, 2004).

2.2 Comfort Condition in Malaysia

The ASHRAE definition of comfort is "that condition of mind that expresses satisfaction with the thermal environment" (ASHRAE 1997). Comfort is affected by several factors, generally classified as: 1) environmental: air temperature, air movement, humidity and radiation; 2) personal: metabolic rate, state of health and clothing; and 3) contributing: acclimatization, body shape and subcutaneous fat.

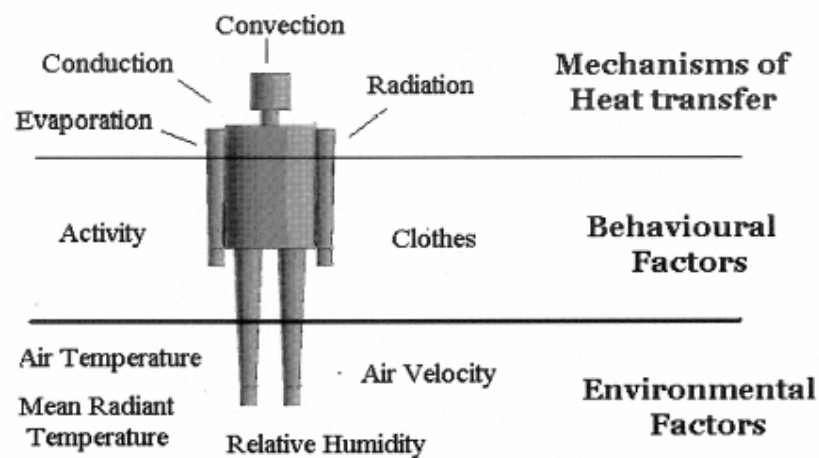


Figure 2.6: The human body interactions with surrounding (Al-Mogbel, 2004).

An overall view of the climatic condition in Malaysia indicates that main factors that affect thermal comfort in this region area solar radiation, high temperature and high humidity (Samirah, 1998). Thermal comfort requirement in hot and humid conditions of Malaysia calls for the minimization of heat gain by the building fabric through solar radiation as well as heat gain by the human body while maximizing heat dissipation from the body by ventilation and evaporative cooling. The indoor comfort condition in building in Malaysia comfort to the ASHRAE Summer Comfort Zone described in the ASHRAE Handbook Fundamental (1989).

All studies about indoor comfort in hot and humid climate indicated a higher neutral temperature than that predicted by ASHRAE.

2.2.1 Neutrally Temperature

The analytical method of evaluating the comfort zone for Malaysia have been studied by several authors (Rajeh, 1988; Abdul Malek and Young, 1993; Zain Ahmed, Sayigh and Othman, 1997; Abdul Rahman and Kannan, 1997), using the “Neutrality Temperature”. This is the temperature at which the respondents in the various studies experienced neither warm or cool, which is a state of “neutral” or “comfortable”. It is the mid point of the comfort zone, as an average value for many experimental subjects. There four factors that can combine together to produce different neutral temperature for the individual: thermal environment, level activity, thermal insulation of the clothing and physiological state of the individual. For adult the neutrality temperature range from 17°C to 30°C The observed range of neutrality temperatures is therefore effectively 13 degree. But it is necessary to conclude that acclimatization also had an affect on the temperature required for thermal neutrality. At this stage it is intended to compare three set of neutrality temperature derives from different authors. Humphreys (1978) studied data from over thirty thermal comfort studies in various different climates and revealed that a very close correlation existed between thermal neutrality and the monthly mean outdoor air temperature. The comfort temperature or neutrality temperature can be predicted from the linier equation for naturally ventilated building as:

$$T_n = 11.9 + 0.534 \times T_o \quad (1)$$

Where,

T_n = predicted neutral temperature

T_o = mean outdoor temperature for the month

The residual standard deviation is 1°K

The range of application is from 10°C to 33 °C

According to Nicol (1994) results of field studies of thermal comfort in different parts of Australia conducted by Auliciems (1981) supported Humphreys's ideas and developed the following relationship for all buildings whether climate controlled for outdoor air temperature between 5°C and 30 °C

$$T_n = 17.6 + 0.31 \times T_{av} \quad (2)$$

Where,

T_n = neutral temperature with $\pm 2^\circ\text{K}$ range

T_{av} = mean air temperature of the month

Szokolay recommended the use of the annual mean temperature (AMT) for applied Auliciems's equation for Kuala Lumpur data (Rajeh, 1988).

$$T_n = 17.6 + 0.31 \times T_{amt} \quad (3)$$

Where,

T_n = neutral temperature with $\pm 2^\circ\text{K}$ range

T_{amt} = annual mean air temperature of the month

Rajeh (1988) used Auliciems neutrality temperature equation (combining the free running and actively controlled buildings) to define the comfort temperature of Malaysian and proposed a bioclimatic chart showing the comfort zone for Malaysia based on Szokolay (1984) version of the bioclimatic chart. He used the climatic data of Kuala Lumpur and found that comfort range between 26.6°C and 30°C was acceptable with the neutral temperature of 26.1°C. Climate chamber studies conducted by Abdul Malek and Young (1993), and field study by Zain Ahmed, Sayigh and Othman (1997). Both studies indicated a higher neutral temperature than that predicted by ASHRAE. In fact the neutral temperature found in the field study conducted by Abdul Rahman and Kannan (1997) in naturally ventilated building agreed well with Humphreys adaptive approach. According to Szokolay (1997) with the width of the comfort zone taken

to be 5°C, thermal comfort temperatures extends approximately about 2.5°C above and below the neutral temperature. While Humphrey's equation gives a good approximation of a single comfort temperature in free running buildings, the thermal comfort zone defined using solely this technique does not accommodate the influences of thermal comfort in hot and humid climates. McFarlane (1958) suggested the following adjustments to be made for comfort zones in naturally ventilated buildings for zones less than and greater than 30° latitude: for each 10% increase in relative humidity above 60%, the thermal comfort zone temperatures should be lowered by 0.8°C, for each 0.15 m/s of air flow past exposed skin up to dry bulb air temperature of 33°C (mean skin temperature), the thermal comfort zone temperatures should be raised by 0.55°C. According to Razak (2004) and Samirah (1998) Szokolay in 1997 took the analysis revealed that there no cooling effect below 0.25m/s and the existence of 1.5m/s of air velocity would allow the extension of the upper limit by 6° C. He devised a procedure for plotting the comfort temperature and comfort zone. However, only Szokolay's revised versions of the effect of air movement on the comfort temperatures are used in the calculation:

$$dT = 6 \times (v - 0.25) - (v - 0.25)^2 \quad (4)$$

where,

dT= temperature reduction

v = air velocity

Using this equation, the upper limit of the comfort zone can be extended by providing natural ventilation or some form of air movement. With air movement of 1m/s recommended by most researchers, the upper limit of Malaysia's comfort temperature can be extended by about 4° C. However, an air flow of 1.5m/s, which is considered still acceptable for hot environment, would be allow the extension of upper temperature limit by 6° C. In extreme cases, the air velocity of 2 m/s is acceptable and the extension would be 7.4 K that the highest acceptable temperature would be 37°C. This cooling effect is very similar to the suggestion given by MacFarlane.

2.2.2 PMV

All of the comfort indices mentioned earlier has used a graphical presentation to display their results. Several of these methods (i.e., ASHRAE's and Givoni's BBCC) superimposed these results on top of a psychrometric chart. Unfortunately, this limits the possible uses of these methods. An alternative, proposed by the Danish scientist, P.O. Fanger, in 1972 used a mathematical model for assessing human comfort conditions. Fanger proposed that human thermal comfort could be derived from a heat balance equation. According to Fanger, the range of comfort could be defined by a subject's vote on a seven-point scale (Fanger 1972). A complete description of the index PMV is described numerically as: cold (-3), cool (-2), slightly cool (-1), neutral (0), slightly warm (+1), warm (+2) and hot (+3). From his proposed comfort equation, Fanger also proposed a "Predicted Mean Vote" (PMV) and "Predicted Percentage of Dissatisfied" (PPD). Fanger's heat balance equation and PMV is useful for this research in terms of how the measured and simulated environmental parameters can be used to predict the comfort level in a space (Sreshthaputra, 2003).

2.2.3 Comfort Zone in Malaysia

The comparative comfort zone, using above three equations and the annual mean air temperature of the month worked out from the climatic data for IES weather data as given in figure 2.7. This will give a general picture of the range of comfort zone for Malaysia. The single value resulted from this comparative study is checked with previous study. With the width of the comfort zone taken to be 5° C (Szokolay, 1997), thermal comfort temperatures extends approximately about 2.5° C above and below the neutral temperature. Taking the neutral temperature of 26°C in free running building as an illustration, as this research is concentrated on naturally ventilated buildings, the upper limit of the comfort zone would then be 28.5°C. This neutral temperature is for conditions without air movement.

The most comfortable periods appeared to be between October to January, which is closely related to the south solstices and the monsoon seasons. The most uncomfortable periods occurred during April to June, which is month between the equinoxes and north solstices, that coinciding well with the inter monsoonal periods. The neutral temperature maxima and minima area approached in June and December respectively. The north-east monsoon (from December to January) appears to have significant effect in lowering the neutral temperature.

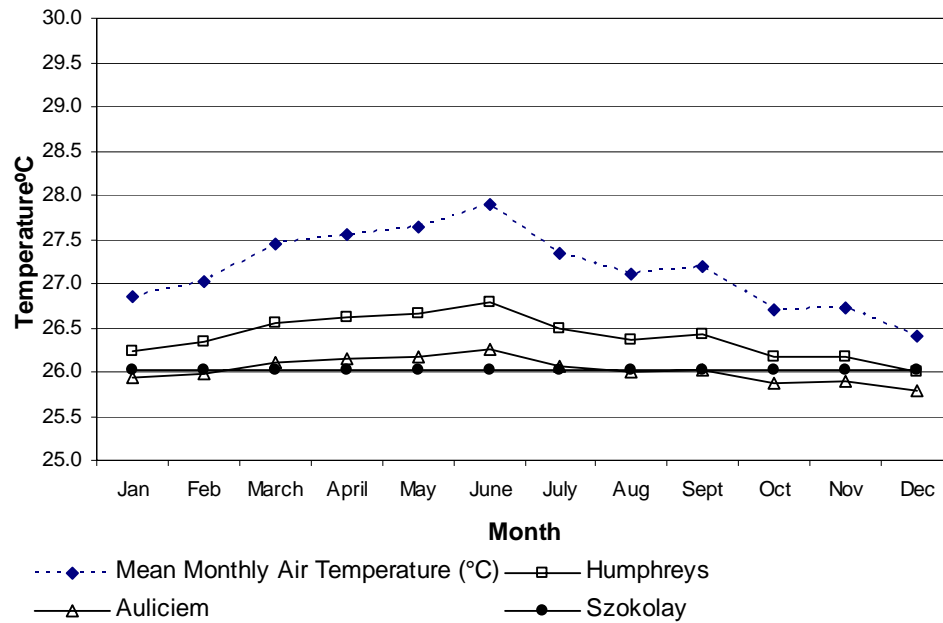


Figure 2.7: Neutral temperature on the IES monthly data

Daily climatic patterns in the tropics required climate conscious building design strategies to achieve thermal comfort. Outdoor temperature and humidity for monthly peak day is plotted in Figure 2.8. According to the fig.2.8 the outdoor air temperature reached to 33°C between 10:00 to 16:00 and during this period the relative humidity is at its minimum. The lowest temperature was reported as 22.7°C at 05.00 h and the average temperature is about 27°C. According to Szokolay comfort formula, the neutral temperature needed to maintain at 28.5°C. Generally, the daytime measured air temperature between 10.00h and 21.00h are above the require comfort level temperatures except peak day on May, September, October and December. It is shown that the range of comfort for climatic data for Malaysia is given as 10.00-16.00, and it is compatible to Webb (1952) empirical results for monthly peak days.

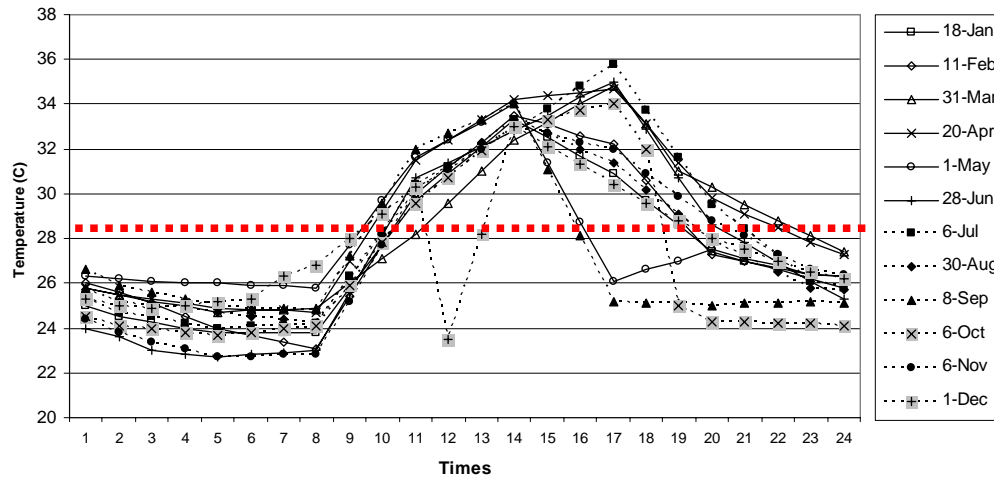


Figure 2.8: Hourly dry bulb temperature on the IES monthly data

2.3 Summary

Malaysian climate condition influenced by the monsoon, the land and sea breezes. Weather data from IES weather data for the monthly peak days were analysed to compare between IES Kuala Lumpur data and Subang Meteorological Station weather file data (2000-2004) as a representative year. Comparisons were carried out on wind speed, solar radiation, air temperature and relative humidity. The impact of winds speed, temperature and humidity were discussed for further comfort analysis in next section. Thereby, it is assumed that using the monthly peak day data may provide relevant climatic data for accurate wind speed, solar radiation, temperature and humidity which represents the hot and humid climates like in Malaysia. The comparison of empirical and analytical approach appears to be more practical method to be employed in determining Malaysia's comfort or neutral temperature. As regards to the thermal comfort range for Malaysian climate, Webb's (1952) recommendation of air temperature 30°C for the upper limit and 26.6°C the lower limit is acceptable with the neutral temperature of 26.1°C by empirical method. Based on the most current data, the neutral temperature for Malaysia, using Szokolay neutrality temperature equation was found to be 26°C for free running building which is the centre of the comfort zone of Malaysia. The comfort range based on analytical approach is close with empirical approach.

CHAPTER 3

METHODOLOGY

This research is divided into three main stages. First, is the research design; second, IES simulation; and lastly third, development of simplified model of the PPRT house model. The methodologies planned for the research are described in this chapter. These methodologies were reviewed from selected literatures and redefined specifically for the purpose of this research.

3.1 Research Design

In order to achieve the aforementioned set of objectives, the following steps are suggested: preparing climate data, IES software validation, simulation of PPRT house model and thermal comfort analysis. For this study, the climate data of Malaysia with Kuala Lumpur weather data will be adopted to present of analysis, and to determine trend of monthly dry bulb temperature, wind speed and relative humidity available for thermal comfort in PPRT house. Climate data consist of annual climate data and selected maximum and minimum peak days of dry bulb temperature each month. The effect of thermal building interaction for thermal comfort is quite difficult to be determined by analytical means. The simplest means is to investigate by using computer simulations of both the climate data and buildings. The IES is the instrument that is used to model the PPRT house thermal comfort. IES validation is done by comparison between field study and IES simulation. This step will involve the testing of a variety PPRT house models in

order to fulfill some the previous stated objective. A typical unit of a PPRT house model (the existing orang asli house, the government initiated PPRT house and the proposed comfortable PPRT house) is built to a scale of 1:1. The testing of the models exclusively is divided into two parts to ease the comparison between various type pf thermal comfort performances.

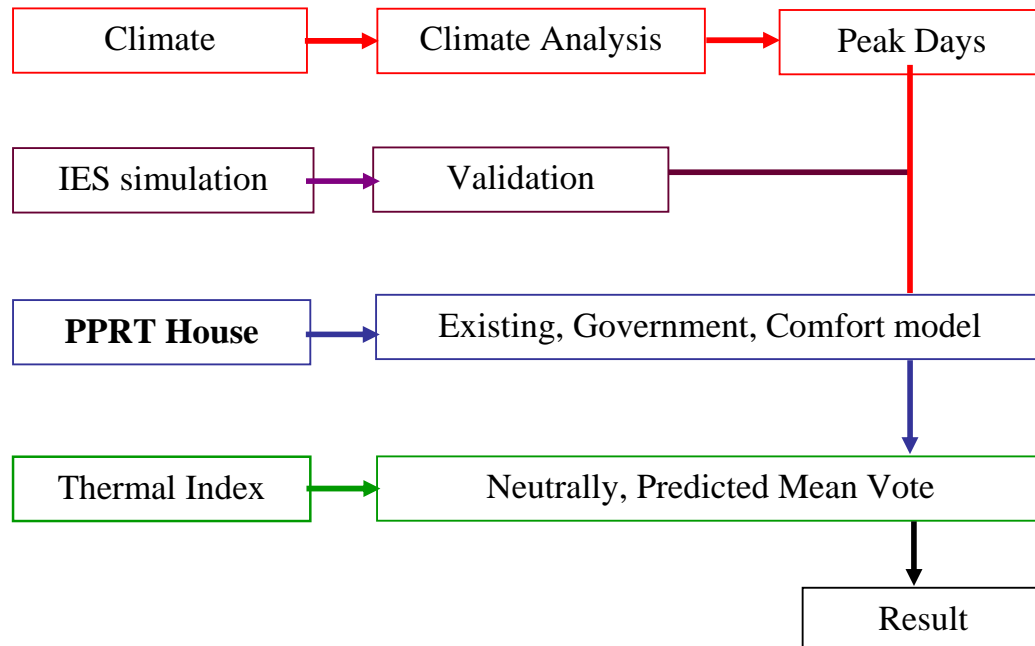


Figure 3.1: The research schematic design

3.2 IES Simulation

The Integrated Environment Solution is an integrated suite of applications linked by a Common User Interface (CUI) and a single Integrated Data Model (IDM). This means that all the applications have a consistent “look and feel” and that data input for one application can be used by the others. Modules such as “ApacheSim” for thermal simulation, “Radiance” for lighting simulation, and “SunCast” for solar shading analysis are available. “Model IT” is the application used for input of 3D geometry used to describe the model.

3.2.1 IES Modeling Methods

The Component modeler is a model building element in the IES. It allows the user to create a library of components which can then be placed within the model. Components are geometrical entities and can be used to model things such as desks, chairs, computers, etc. These can then be placed in the model by Model IT. The Component modeler uses many of the same drawing and editing tools that are used in Model IT. The material composition of the walls, windows and other elements of the building fabric are described using the program APcdb (Apache constructions database manager). APcdb provides databases of materials and constructions which may be imported into the building and edited as necessary. Constructions are built up from layers with specified thermo-physical properties and widths. In the case of glazing constructions the layer properties include solar transmittance, absorptance and reflectance characteristics. Construction details may be passed between projects using a Construction Template. The following utilities are also provided:

- Calculation of U-values and admittance parameters
- Calculation of glazing angular solar transmission properties
- Condensation analysis

a. Model IT

Model IT is the model building component of the IES. Model IT allows the user to create the 3D models required by other components within the IES. Model IT is designed to enable appropriate levels of complexity to be incorporated within a model across the entire design spectrum. At the sketch design or feasibility stage, basic models may be generated from scratch using a variety of simple modeling tools, in order to conduct preliminary performance appraisals or comparative studies. Similarly, at the other end of the design process, fully worked computer aided design (CAD) files may be attached to Model IT and using the tools provided, three-dimensional building spaces may be generated rapidly by tracing over the DXF outlines. Moreover, in the case of the optional Construct/DXF module, a complete

model including doors and windows may be generated from a DXF file entirely automatically. Construct DXF is used to produce data for IES's thermal, shading analysis, lighting and building design appraisal software by scanning ordinary DXF drawings of building plan layouts, and generating a 3D building data model, within the Model IT environment. Construct DXF simplifies and accelerates the preparation of data for a wide range of building design studies including thermal design, shadow modeling, dynamic thermal simulation, multi-zone airflow analyses and electric lighting/daylighting studies. Construct DXF is run from within Model IT (IES's 3D modeling tool). The two programs together provide the user with a comprehensive set of tools to allow the generation of a full three-dimensional spatial building model and associated non-graphical attribute data from DXF format drawings. The familiar windows style interface is used to provide dialogue box data entry for information unobtainable from the drawing file(s), such as storey, window and door heights, element constructions, building and room default attributes, and for the subsequent editing of room and room element data. The data model can be generated from DXF drawings containing any conventional drawing element (arcs, shapes, cells, B-splines, etc.). No special elements or attributes are required. In addition to single floor plans, Construct DXF will cater for several buildings on one site, multi-storey buildings, and buildings that bifurcate as they rise up. The information from the data model generated by Construct DXF is used to generate files for IES's thermal analysis, shadow analysis, airflow or lighting software. Results from the calculation software are read back into Model IT and if required, these results can be viewed within the Model IT environment. Additionally, luminaires can be placed and modified in the 3D model either directly by the user (for subsequent point-by-point analysis by the lighting calculation software) or as a result of performing a lighting design with the lighting software.

b. Construction Database, classes and categories

The Constructions database (formerly called APcdb) provides facilities for viewing and editing constructions used in the thermal applications ApacheCalc, ApacheLoads and ApacheSim. A construction defines the thermal properties of a

building element such as a wall, ceiling or window. It consists of a number of layers of different materials, together with thermal properties of the materials, surface properties and other attributes used in thermal analysis. Constructions are divided into two classes – opaque and glazed – with different thermal parameter sets. In the case of opaque constructions thermal capacity, as defined by density and specific heat capacity, is important. Glazed constructions, by contrast, are to a good approximation mass-less, but they require properties characterizing their solar transmission properties. The construction categories correspond to categories of building element used for construction assignment in the Apache View. The thermal parameter sets for constructions are broadly similar for categories belonging to the same class (opaque or glazed), but in some cases differ in respect of their building regulations parameters and default values for surface resistance.

The purpose of the constructions database is to assemble a set of constructions for use in the project. The function of the constructions database is to facilitate the process of setting up and checking this data. There are many different classes of parameter set of opaque and glazed construction. These classes are further broken down into categories:

- Emissivity: the emissivity of the outside surface of the construction. Most materials have an emissivity of about 0.9. Lower values apply to unpainted metals.
- Solar absorptance: the fraction of incident solar radiation absorbed by the surface. This is a function of the colour and surface finish.
- Resistance: the thermal resistance between the outside surface and its environment. This is the reciprocal of the outside heat transfer coefficient, which is made up of convective and radiative components. Ticking the default box displays a standard value determined from the construction category, together with the *Wind exposure* in the case of external adjacency.
- Floor area: The total internal area of the floors to which this construction is assigned.
- Exposed floor perimeter: The exposed perimeter length of the floors to which this construction is assigned.

- External wall thickness: The average thickness of the external walls along the floor perimeter.
- Ground conductivity: The thermal conductivity of the ground under the building. Using these parameters the software will calculate and display the CIBSE uninsulated U-value. If this is less than $0.25 \text{ W/m}^2 \text{ K}$ it will be used to create a bespoke floor construction that will be assigned to the relevant floors in the notional building. If the construction belongs to the Door category an additional parameter must be set for UK Building Regulations compliance testing.
- Vehicle access or similar large door: a category of door to which special rules, including more stringent U-value requirements, are applied in the Building Regulations.
- Wall or roof element: select this option if you have used a door to represent elements of a wall or roof. This will place these elements in the correct category for Building Regulations purposes.
- Construction layers (outside to inside), the construction may consist of up to 10 homogeneous layers, which are listed in order from outside to inside. With the exception of air gaps, each layer has a thickness and a material. The material has a set of properties which are stored in the Project Materials database, but which may be edited within the layer. Any the government initiated PPRT house materials created by edits of this kind will be added to the list of Project Materials. Air gaps (which can include cavities filled with other gases such as argon) are assigned a thermal resistance in place of a material.
- Resistance: (air gap only) the thermal resistance of the air gap, taking account of both convection and radiation across the gap.
- Specific heat capacity: the specific heat capacity of the material.
- Conductivity: the thermal conductivity of the material.
- Density: the density of the material.
- Vapour Resistivity: the vapour resistivity of the material or air gap. This field is blank for many materials, but a value must be supplied before condensation analysis is carried out.
- Category: the material category from the system materials database.

c. Site Data

Location data is about latitude, altitude, longitude, time adjustment, daylight saving period, ground reflectance, terrains type and wind exposure. The latitude is expressed as decimal degrees north or south. In other words, 20° 30" N should be entered as 20.50 and the drop-down box beside the number set to N. The latitude of the building is expressed in decimal degrees (positive for northern locations, negative for southern locations). Altitude is the height above sea level of the building. For locations below sea level, negative values are appropriate. The data is used in the calculation of solar gains and atmospheric pressure in heat gain. The longitude is expressed as decimal degrees east or west. In other words, 20° 30" E should be entered as 20.50 and the drop-down box beside the number set to E. The building longitude is in decimal degrees. The longitude is regarded as increasing westwards from Greenwich, so 20° East of Greenwich is rendered as entered as 340°. Time adjustment is the local time correction applicable for daylight saving time. The value must be approximated to the nearest hour. Positive is in advance of sun time. Ground reflectance is a measure of the ground albedo (K_r). It is used for the calculation of ground reflected radiation on building facades. Terrains type such as country, suburban and city define how the wind speed will vary with height, dependant upon the local terrain. These definitions are based on ASHRAE 2001 wind speed profiles. This data affects the natural ventilation air exchange rates when the velocity profile changes with height in relation to the choice of terrain type. The wind exposure index is used to calculate the external surface resistance of walls, windows, roofs etc. The wind exposure divided into three categories: sheltered sites (e.g. city centres), normal exposure sites and sites with severe exposure (e.g. coastal). In most cases, the peak summertime conditions will occur for a sheltered site. This is because the higher surface resistance levels give rise to higher sol-air temperatures on external surfaces. Higher surface resistance levels also reduce the conduction of heat out of the building at night.

3.1.2. Solution Method

Apache Simulation is a dynamic thermal simulation program based on first-principles mathematical modeling of the heat transfer processes occurring within and around a building. ApacheSim qualifies as a Dynamic Model in the CIBSE system of model classification, and exceeds the requirements of such a model in many areas. The program provides an environment for the detailed evaluation of building and system designs, allowing them to be optimized with regard to comfort criteria and energy use. Amongst the issues that can be addressed with ApacheSim are:

- Thermal insulation (type and placement)
- Building dynamics & thermal mass
- Building configuration and orientation
- Climate
- Glazing properties
- Shading, solar gain & solar penetration
- Casual gains
- Air-tightness
- Natural ventilation
- Mechanical ventilation
- HVAC systems
- Mixed-mode systems

Within ApacheSim, conduction, convection and radiation heat transfer processes for each element of the building fabric are individually modeled and integrated with models of room heat gains, air exchanges and plant. The simulation is driven by real weather data and may cover any period from a day to a year. The time-evolution of the building's thermal conditions is traced at intervals as small as one minute.

Results output by the simulation include:

- Comfort statistics
- Energy consumption
- Carbon emissions
- Room load statistics
- Plant sizes

- Detailed performance measures including hourly room temperatures (air, mean radiant and dry resultant), humidity, plant loads, casual gains and air exchanges
- Surface temperatures for comfort studies or CFD boundary conditions

a. Simulation Principles of Heat Conduction and Storage Fundamentals

ApacheSim deals separately with each of the fundamental heat transfer and control processes affecting building thermal performance. In ApacheSim modeling assumptions, conduction in each building element (wall, roof, ceiling, etc) is assumed to be uni-dimensional. Furthermore, the thermo-physical properties and c of each layer of the element are assumed to be uniform within the layer. The system of equations is closed by the application of appropriate boundary conditions and the stipulation that W is continuous at the layer boundaries.

ApacheSim adopts a finite difference approach to the solution of the heat diffusion equation. This involves first replacing the element with a finite number of discrete nodes at which the temperature will be calculated. To improve accuracy and stability a combination of explicit and implicit time-stepping is often used. The Crank-Nicholson semi-implicit method is an example of such a scheme. Another is the ‘hopscotch’ method, which applies explicit and implicit time-stepping to alternate nodes of the construction. This is the method adopted by ApacheSim. The advantages of this method are a high level of accuracy combined with very efficient computation.

At the air mass and furniture modeling, the effect of heat storage in the furniture may be incorporated into the analysis. A facility is offered for modeling furniture on the assumption that its temperature closely follows that of the air. Under this assumption its effect is to increase the effective thermal mass of the air by a factor termed the furniture mass factor. In cases where the furniture has substantial

thermal capacity, it is best to model it by introducing additional internal walls, with suitable thermal properties, into the room model.

b. Convection Heat Transfer Fundamental

Convection is the transfer of heat (and in general other physical quantities) resulting from the flow of fluid over a surface. For the purpose of the present discussion the fluid is air and the surface is an element of a building. If the convective air flow is driven by external forces – for example wind or mechanical ventilation – it is referred to as forced convection. The term natural convection describes convection arising from buoyancy.

Exterior Convection occurring at the external surfaces of the building is predominantly wind-driven forced convection. In ApacheSim external forced convection is modeled with a wind speed dependent convective heat transfer coefficient calculated from McAdams' empirical equations. Variables on the simulation weather file are recorded at hourly intervals. Linear interpolation is applied between the recorded values to compute values at each simulation time-step. Provision is made in the constructions database program APcdb for the user to override this calculation procedure with a fixed value for the external convection coefficient. Interior convection has a number of options for modeling convection heat transfer between air masses inside the building and the adjacent building elements:

- Fixed convection coefficients specified by CIBSE
- Variable convection coefficients calculated according to CIBSE procedures
- Variable convection coefficients calculated from the relations the proposed comfortable PPRT house by Alamdari & Hammond.
- User-specified fixed convection coefficients

The first three options may be selected from the Simulation Options facility of the

ApacheSim interface. The fourth option will apply to any constructions for which fixed internal surface coefficients are applied in the constructions database program APcdb. For such constructions the fixed value will override the method selected in the Simulation Options interface.

c. Heat Transfer by Air Movement

ApacheSim models the following types of air movement:

- Pre-specified air exchanges, classified as infiltration, natural ventilation or mechanical ventilation. These air exchanges may be sourced from outside air, outside air modified by a temperature offset, air at a (possibly varying) temperature defined by an absolute profile or air from another room. The rate of air flow is specified before the simulation, but may be made to vary with time by means of a profile. If the profile is a formula profile, the air flow rate may also vary with simulation variables such as room air temperature.
- Air flows calculated by MacroFlo. MacroFlo calculates natural ventilation air flows arising from wind and stack pressure (buoyancy). It also takes account of flow imbalances generated by HVAC systems. MacroFlo runs in tandem with ApacheSim and the calculations of the two programs are interdependent.
- Air flows specified or calculated by ApacheHVAC. Like MacroFlo, ApacheHVAC is fully integrated with ApacheSim and its ducted mechanical ventilation rates are superimposed on other air flows dealt with by ApacheSim. The calculation of air flow rates by MacroFlo and ApacheHVAC is dealt with in the sections devoted to these programs.

d. Thermal Radiation Fundamentals

Building surfaces emit thermal radiation by virtue of their absolute temperature. For small surface element (dA) of a Lambertian emitter the radiation flux emitted into a small solid angle ($d\Omega$) lying in a direction making an angle to the

surface normal is surfaces also absorb a proportion of the radiation they intercept. By Kirchhoff's law the fraction of incident radiation that is absorbed by a surface is equal to its emissivity, ϵ . These results represent an idealisation of the physics of radiation emission and absorption in that they assume Lambertian angular characteristics and do not enter into the detail of wavelength dependence (the grey body assumption). However, they provide a sound basis for modeling radiation exchange in buildings.

The emission and absorption of thermal radiation by building surfaces represents an important mechanism for heat transfer. The following discussion centres on the exchange of radiation between solid surfaces. Gases and suspended particles in the air also participate in radiant exchanges and this can be important both inside and outside the building. Thermal radiation is described as long-wave if it is characteristic of temperatures normally experienced in the human environment. Solar radiation lies in a shorter wavelength band and is treated separately. Surface properties are often significantly different in the long-wave and solar wavelength bands, giving rise to differences between surface emissivity and solar absorptance. Transmission properties are also strongly wavelength dependent: glass is mainly transparent to the solar spectrum but almost opaque in the long wave.

e. Interior and Exterior Long-wave Radiation

By calculating shape factors and accounting for scattering (radiosity), it is possible to construct an accurate model of radiant heat exchange in an enclosure. For practical purposes, however, simpler models are adequate. Models based on the concept of mean radiant temperature reduce the computational effort involved in radiant exchange calculations by a large factor. Such models introduce a single (fictitious) radiant node which serves as a clearing house for all surface radiant exchange transfers. In an n -surface enclosure this reduces the number of heat transfer pathways from approximately $\frac{1}{2}n^2$ to n . The various mean radiant temperature models differ by small amounts in the values assigned to this coefficient. ApacheSim

adopts the CIBSE mean radiant temperature model, which provides a good representation of radiation exchange where it can be assumed that the emissivities of the surfaces bounding the enclosure do not differ greatly from one another (which is almost always the case). Exterior building surfaces receive long-wave radiation from the sky, the ground and other objects in the environment. They also emit thermal radiation. The difference between radiation emitted and radiation absorbed constitutes the net long-wave gain (which in most instances is negative). The model adopted by ApacheSim for the treatment of exterior long-wave radiation follows work undertaken for the CEC European Solar Radiation Atlas and endorsed by CIBSE in Guide A.

f. Solar Radiation Fundamentals: Calculation of Incident and Distribution of Diffuse Solar Radiation

To a good approximation, the sun is a black body radiator with a surface temperature of 5800K. The energy it radiates produces a radiation flux at the top of the earth's atmosphere which over the course of a year averages to 1353 W/m². Filtering by gases in the atmosphere and by cloud and particulates means that fluxes at the earth's surface are variable and typically considerably less than this figure. Further factors influencing solar radiation at ground level are varying sun angles and diffusing of the radiation by the atmosphere. Solar radiation incident on building surfaces can be broken down into three main components: direct (beam) radiation emanating from the region of the sky near to the sun's disc, diffuse radiation from the sky vault, and radiation scattered by the ground. Direct radiation is significantly modified by shading by nearby buildings and landscape features. Solar radiation enters the building through glazing and is absorbed (after repeated scattering) by internal surfaces. Part of this radiation may be lost by being re-transmitted out of the building through glazing. The effect of absorption and scattering by exterior surfaces (both opaque and transparent) is also significant.

ApacheSim is driven by actual weather recorded at hourly intervals and stored on a simulation weather file. The solar altitude and azimuth are calculated from the location of the site where the weather was recorded, together with time zone and summertime clock adjustment information. This information is also used by the programs SunCast and SunCast Lite to generate shading data for ApacheSim, and it is important that the same location data is used in both cases. ApacheSim calculates, at each time-step, the solar flux incident on every external building surface. This analysis covers the case where the sky diffuse radiation is assumed to be isotropic, the factors involving rising from integration of this isotropic radiation over solid angle. If the user selects the anisotropic diffuse solar radiation model from the Simulation Options menu the calculation designates a portion of the diffuse radiation circumsolar, which it treats as if it emanated from the sun position. The proportion of the diffuse radiation designated circumsolar varies with the intensity of the beam radiation.

Diffuse radiation incident on an exposed surface is the sum of components from the sky, the ground, and certain types of shading object. Shading objects block diffuse sky solar radiation to a degree determined by a diffuse shading factor. Diffuse shading factors for remote shading objects are calculated optionally by SunCast (or assumed to be 1 if not calculated). This type of shading applies to both glazed and opaque surfaces. Diffuse shading factors for construction-based shades defined in APcdb and classified as 'local' (side-fins, overhangs and balconies) are calculated for each instance of the construction occurring in the model. Where both remote and local shades apply to the same surface, their diffuse shading factors are combined by taking the lower of the two factors. This gives a conservative estimate of the degree of shading. SunCast and 'local' shading objects are assumed to scatter ambient radiation, as well as blocking diffuse radiation from the sky. This gives rise to an additional term in the diffuse incident flux. For the purpose of estimating this flux, shading objects are assumed to be vertically oriented, adjacent to a large vertical wall, and both wall and shading object are assumed to have a reflectance of 0.3. Ground reflection is accounted for, but direct and circumsolar radiation is excluded from the calculation. Construction-based shades of the 'external' type (shutters and louvres) have a sky shading factor and a ground shading factor set in APcdb (both of

which may optionally be calculated from the direct shading characteristics). These factors attenuate the radiation incident on the glazed element from the sky, the ground and the other types of shading object. Radiation scattered by shading devices of this type is ignored.

The diffuse component of solar radiation incident on an external glazed element – the sum of components from the sky and the ground – is partially transmitted and partially absorbed in the element. The transmitted portion is distributed over the interior building surfaces as follows. In simple cases the diffuse radiation entering a room through a glazed element is distributed over the other surfaces in the room in proportion to their areas. An exception to this rule may apply in the case of glazed, external receiving surfaces. If the shape factor implied by the area-weighted distribution is greater than the maximum theoretical shape factor between the receiving surface and the source surface (given their areas and relative orientation) the shape factor is reduced to the theoretical maximum. The radiation deficit is then spread over the other receiving surfaces in proportion to their estimated shape factors. This exception prevents windows in the same façade from radiating directly to each other. Such windows are treated effectively as one large window. Surfaces receiving diffuse radiation distributed in this way reflect, absorb and (if transparent) transmit it in appropriate proportions. ‘Holes’ are treated as perfectly. Radiation transmitted through transparent partitions in the course of these processes is treated in a similar way to radiation entering the building from outside. No shape factor adjustment is applied, however. A portion of any radiation distributed to external windows is lost by transmission back out of the building. The above steps are repeated up to 10 times to distribute the diffuse radiation through the building. Any residual radiation at the end of the process is assigned to room surfaces in a final modified acceptance distribution.

g. Solar Transmission by Glazing and Opaque Surface

From this data the program calculates the following derived parameters for the construction as a whole:

- Solar transmission, absorptance and reflectance parameters at 10 angles of incidence
- Parameters describing the distribution of solar absorption within the construction
- Separate U-values for the glazing and the frame

For each glazing layer (pane) the solar characteristics are checked for consistency. An analysis based on the Fresnel equations is carried out for a pane having the given layer refractive index and an absorption parameter (extinction coefficient) that is adjusted to match the given pane absorptance. This is done for two rays with perpendicular polarisations, and the results are combined to give normal-incidence transmittance, absorptance and reflectance values. These are then compared with the values entered for these parameters. The most likely cause of a discrepancy in this comparison is the presence of a reflecting film on the glass surface. In this case the discrepancy is corrected by adding a reflecting film with properties chosen to match the characteristics entered. When the discrepancy cannot be corrected by a modification of this sort, the refractive index is adjusted to produce a match. The derived characteristics are then used to produce transmittance, absorptance and reflectance parameters for 10 incidence angles, again using the Fresnel equations applied to rays of two polarisations. The solar characteristics of the construction as a whole are then calculated for the 10 incidence angles and the two polarised rays. This process in general involves consideration of an infinite number of reflections at glazing/air interfaces. The result is a set of solar transmission, absorptance and reflectance parameters at 10 angles of incidence, the absorptance characteristics being further resolved according to where in the construction the absorption occurs. The absorption parameters are then simplified, without any compromise of accuracy, by replacing each absorption by equivalent absorptions at the external internal surface of the constructions, using an equivalent circuit representation involving the thermal resistances of the layers. During a simulation, whenever solar radiation strikes a glazed surface the interaction of the radiation with the glazing is calculated using the construction's solar parameters. Portions of the incident radiation are transmitted, absorbed, and reflected. For direct (beam) radiation the appropriate angular characteristics are used. For diffuse radiation, the calculation uses hemispherically averaged characteristics. Any frame forming part of the construction is assumed to have a transmittance of zero and an absorptance of 0.55. External

shutters/louvres and internal blinds/curtains participate in the interaction according to their parameters as specified in APcdb. External opaque building surfaces absorb and reflect solar radiation according to their solar absorptance as assigned in APcdb. SunCast and SunCast Lite shading data is applied to external opaque surfaces, and SunCast shading data is applied also to internal opaque surfaces.

3.1.3 IES Procedures

Apache is the name given to the thermal analysis programs in the Virtual Environment. The Apache view provides facilities for:

1. Preparation of input data for the thermal analysis programs ApacheCalc, ASHRAE Loads and ApacheSim
2. Calculations and simulations using ApacheSim, ApacheHVAC, MacroFlo, ApacheCalc, and ASHRAE Loads

The preparation of thermal input data consists of three main tasks:

1. Specification of building location and weather data
2. Specification of building element data (properties of the building fabric)
3. Specification of room data (conditions in each room)

The interfaces to the thermal analysis programs provide facilities for:

1. Setting up the calculations and simulations
2. Specifying the results to be recorded

Data on the global location of the building and the climate to which it is exposed are specified using the program APlocate. The location data includes the latitude and longitude of the site, together with information about the local time zone and any summertime clock adjustment. The weather data covers the requirements of both the heat loss and heat gains calculations and the thermal simulation program. For the heat loss calculation the weather data takes the form of a single outside winter design temperature. For the heat gains calculation the data provides hourly dry-bulb temperatures, wet-bulb temperatures and solar data for one design day per

month. For thermal simulation the weather data is more extensive and is stored on a simulation weather file. This file contains the values of the following weather variables measured at hourly intervals over a year:

- Dry-bulb temperature
- Wet-bulb temperature
- Direct beam solar radiation
- Diffuse solar radiation
- Wind speed
- Wind direction
- Cloud cover

Weather data in these formats is available for a large number of sites world-wide.

In common with other Virtual Environment applications, the Thermal applications derive their geometrical data from the ModelBuilder. This is supplemented with application-specific data provided within the Thermal Application Category. The input data requirements of the thermal applications are summarised below. The data is managed by utility programs invoked from the Application Views. Where possible, applications access common data so that it is never necessary to re-enter values in order to carry out different types of analysis. The efficiency of data input is further enhanced by the use of objects called Templates. Templates bring together groups of thermal input variables so that they can be assigned collectively to sets of rooms, building elements or other objects. Construction Templates store descriptions of constructions for the various categories of building element (walls, floors, windows and so on). Room Thermal Templates store sets of casual gains, air exchanges, plant operation parameters and zoning information associated with rooms of a given type. After a Room Thermal Template is assigned to a room it may be overridden by subsequent ad hoc changes. Templates can be transferred between projects. They offer a powerful means for imposing structure on the input data, maintaining data quality and saving the user time.

The following is a summary of the data required by the thermal applications and the utility programs that manage this data. ApacheSim is a dynamic thermal

simulation program based on first-principles mathematical modeling of the heat transfer processes occurring in and around a building. ApacheSim qualifies as a Dynamic Model in the CIBSE system of model classification, and exceeds the requirements of such a model in many areas. The program provides an environment for the detailed evaluation of building and system designs, allowing them to be optimised with regard to comfort criteria and energy use. Within ApacheSim, conduction, convection and radiation heat transfer processes for each element of the building fabric are individually modeled and integrated with models of room heat gains, air exchanges and plant. The simulation is driven by real weather data and may cover any period from a day to a year. The time-evolution of the building's thermal conditions is traced at intervals as small as one minute.

Results output by the simulation include:

- Comfort statistics
- Energy consumption data
- CO₂emission data
- Room load statistics
- Plant sizes
- Detailed performance measures including hourly room temperatures (air, mean radiant and dry resultant), humidity, plant loads, casual gains and air exchanges
- Surface temperatures for comfort studies or CFD boundary conditions

The simulation engine has the following features:

- Finite difference dynamic heat conduction modeling
- Dynamically calculated surface convection characteristics
- Air temperature, surface temperature and room humidity modeling
- Advanced solar and long-wave radiation exchange models
- External solar shading using data from SunCast
- Solar tracking through an arbitrary number of transparent internal partitions using data from SunCast
- Angle-dependent glazing transmission, reflection and absorption characteristics

3.3 Development of Simplified PPRT Model

The simplified PPRT house model used in the IES simulation is developed from the basic model of the existing orang asli house, the government initiated PPRT house and the proposed comfortable PPRT house, which is identified through inventory exercise as discussed in chapter 1. From the basic model, three sets of simplified model with four cardinal orientations (by introducing thermal comfort performance) of PPRT house model are derived. The development of the simplified PPRT house model is described in the following sections.

3.3.1 The Existing Orang Asli House Simulation Model

The basic simplified existing orang asli house shown in figure 3.2 is a typical configuration with overall size of 5m x 5 m x 3.5m high. This size is to represent 1 living room and 1 verandah on existing orang asli house.

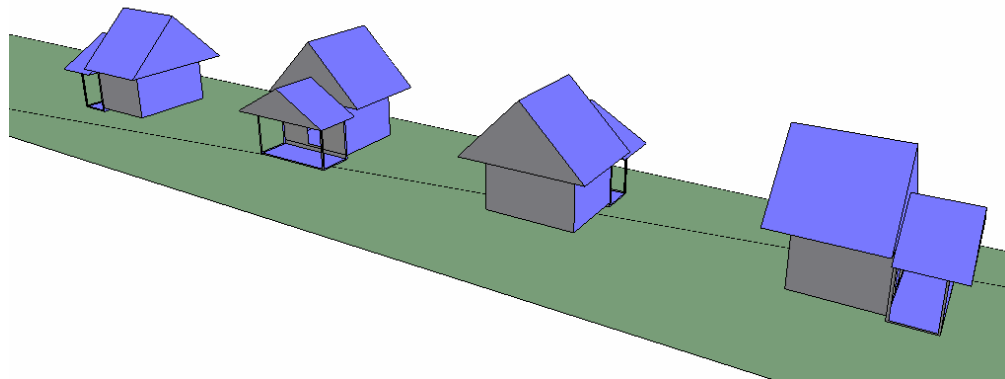


Figure 3.2: The existing orang asli house model in the IES

3.3.2 The Government Initiated PPRT House Simulation Model

The government initiated PPRT house model are the government initiated PPRT house design by government of the existing orang asli house model described in section 3.3.1. In this stage, the government initiated PPRT house model is modified by introducing geometry and material configuration. In this study, the house size is 8.5 m x 6 m x 3 m high. However, when considering the thermal comfort performance, three rooms were simulated: living room, bedroom 1 and bedroom 2.

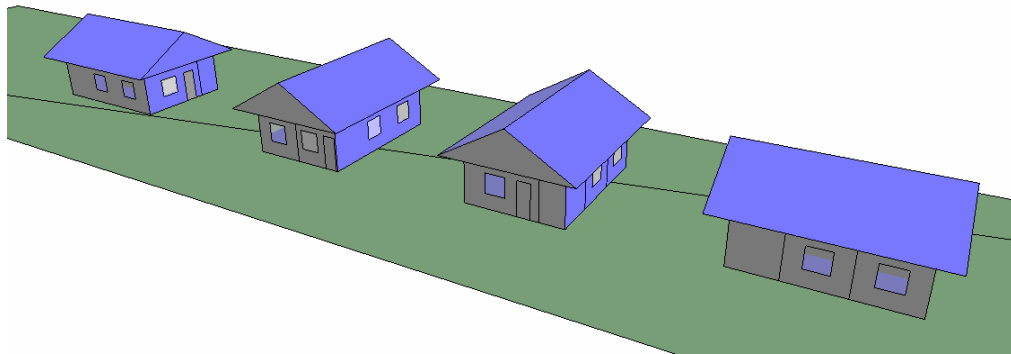


Figure 3.3: The government initiated PPRT house model in the IES

3.3.3 The Proposed Comfortable PPRT House Simulation Model

The the proposed comfortable PPRT house comfortable PPRT house is modification of the the existing orang asli house and government initiated PPRT house model described in last section. In this stage, the the proposed comfortable PPRT house comfortable PPRT house is modified physically into 3 bedrooms, 1 living room and 1 kitchen. The modification is by geometry, material configuration and thermal comfort principle.

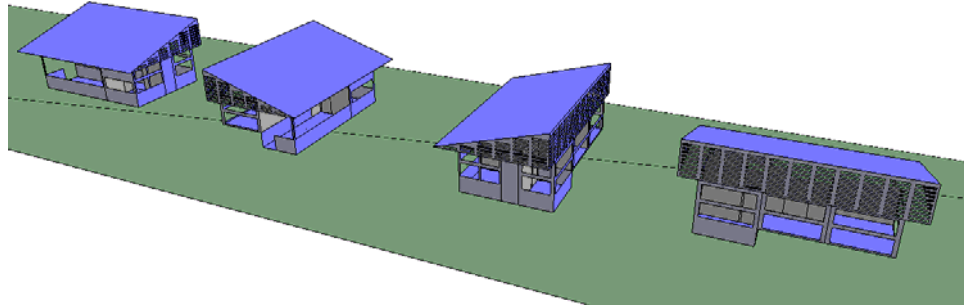


Figure 3.4: The the proposed comfortable PPRT house comfortable PPRT house model in the IES

3.3.4 The simulation data of PPRT House Model

Table 3.1: Construction Input Data for IES simulation

Model	Element	Material	Thickness (m)	U value (Wm ² K)
Existing orang asli house	Roof	Zink	0.05	3.5
	Ceiling	-	-	-
	External Wall	Timber (Oak)	0.2	2.2
	Internal Wall	-	-	-
	Floor	Stone, cast concrete	0.1	0.5315
	Window	-	-	-
	Door	Wood	0.1	0.3488
Government initiated PPRT	Roof	Asbestos Cement Decking	0.15	4.6
	Ceiling	Gypsum plastering	0.1	2.0686
	External Wall	Brickwork	0.22	4.5
	Internal Wall	Brickwork	0.22	4.5
	Floor	London clay, stone, cast concrete	0.2	0.803
	Window	Single Glass	0.1	5.448
	Door	Wood	0.15	0.3488
The proposed comfortable PPRT house comfortable PPRT	Roof	Asbestos Cement Sheet	0.1	2.1
	Ceiling	-	-	-
	External Wall	Plywood	0.1	0.1609
	Internal Wall	Plywood	0.1	0.1609
	Floor	London clay, stone, cast concrete	0.1	0.803
	Window	-	-	-
	Door	Wood	0.1	0.3488

The initial conditions for simulation have been set using the climatic data from the annual hourly IES weather data of Kuala Lumpur. The immediate surrounding environmental conditions were measured at 10 m above the ground. Data for solar radiation, wind speed, wind direction, air temperature and relative humidity were obtained using the IES weather data. The IES program requires inputs representing problem type, model builder (material, type of construction, etc.), simulation conditions, and calculation method (suncast and multi-zone air movement). The problem type is used to activate calculation modules; in this case, thermal calculation and simulation.

3.4 The Validation of Field Study and IES Simulation

In order to validate the IES simulation setting-up, procedures and conditions. A field study was carried out to validate the capabilities of the IES software in generating indoor house temperature and consequently estimating the thermal comfort performance. The results of the field study will justify the validity of the simulation procedures and conditions. According to Sopian (2004), Baskaran and Stathopoulos (1992), method of validation can be performed by comparing the simulation results with measurements.

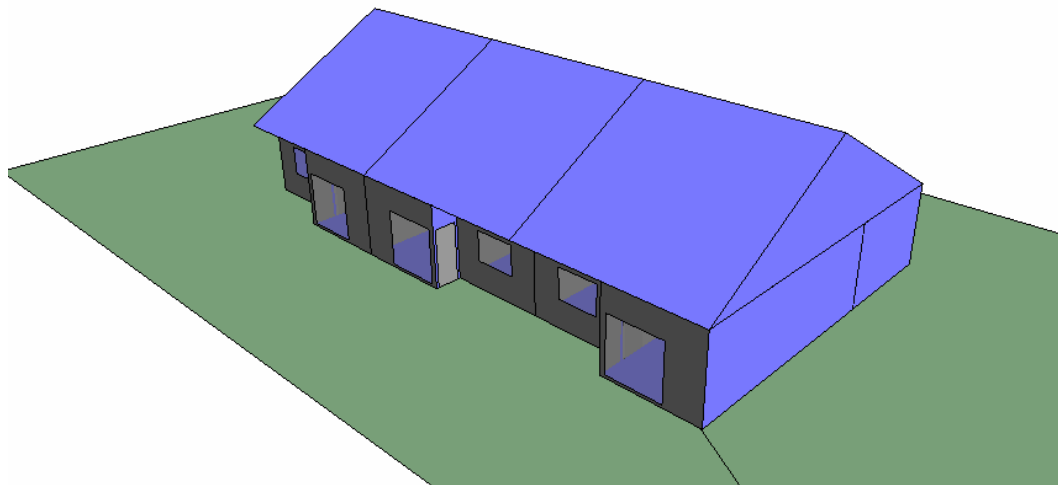


Figure 3.5: The field study house model in the IES

3.4.1 The Field Study Simulation Model

The field study house model is taken from the terraced houses measurement by Nugroho (2006). In this stage, the terraced house model is simplified by introducing geometry and material configuration. Three rooms were simulated: living room, bedroom 1 and bedroom 2, when considering the indoor temperature comparison.

3.4.2 Result and Finding of Field Study Validation

Figure 3.5 shows the plot of points for field measurement and IES weather data on 21 March 2006. The figure shows close agreement between measurement and simulation values. Deviations are within a range of 5% of the calculated dry bulb temperature and relative humidity. For most of the observations, this difference is less than 20% of the calculated values.

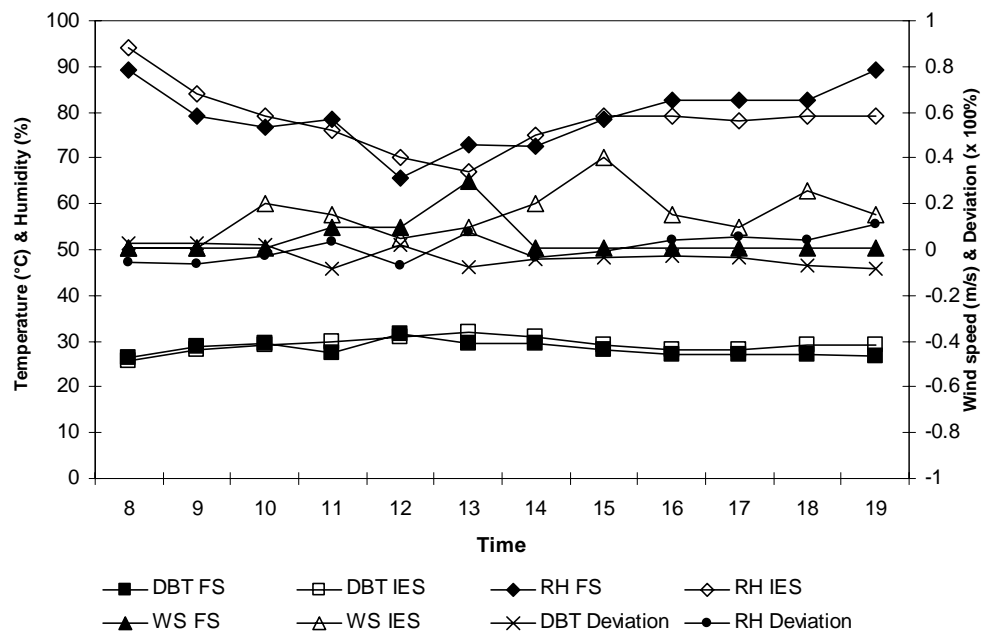


Figure 3.5: Comparison of the dry bulb temperature, relative humidity and wind speed result between field measurement and IES simulation

Figure 3.6 showed a good agreement between IES simulations with the field measurement results. The difference was less than 20% for most of the calculated points on the temperature and the mean deviation were less than 10%. In those cases, the absolute differences were less than 3.2°C. In summary, the outdoor/ambient and indoor air temperature calculated by the IES simulation showed a good agreement with the results of the field measurement.

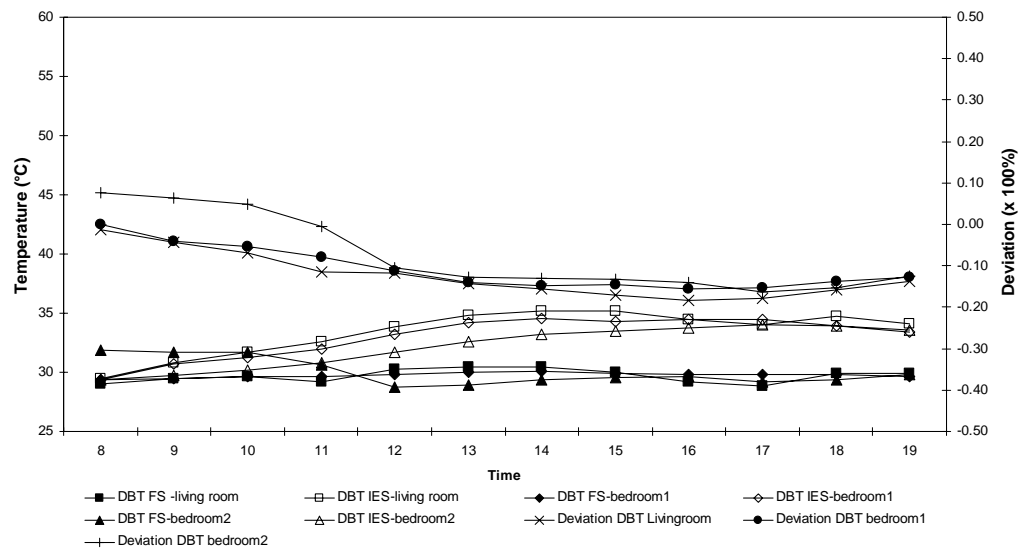


Figure 3.6: Comparison of the dry bulb temperature result between field measurement and IES simulation

Although there are slight differences between the results of IES and field measurement, it can be inferred that the IES modeling is appropriate to reproduce the phenomena occurring in the measurements. The use of the IES model to investigate the performance of the thermal comfort ventilation can be validated.

CHAPTER 4

RESULTS, ANALYSIS AND FINDINGS: THERMAL PERFORMANCE OF PPRT MODEL

This chapter evaluates the simulation results obtained for indoor temperature and predicted mean vote (PMV of comfort index for the PPRT house model tested). The evaluation on indoor temperature and PMV is based on monthly data and selected peaks dry bulb temperature (DBT) days. The thermal comfort analysis is based on the neutrality temperature and comfort index which includes both indoor temperature and PMV. Further, in order to find the correlation between the neutral temperature and comfort index, the minimum air temperature requirement and comfort index performance results are presented in the same graph as a function of building orientation. The impact of PPRT house model is established based on the maximum of decreasing indoor temperature and PMV index. Finally, the comparisons of the results of the three houses designs on thermal comfort performances are discussed.

4.1 Neutrality Temperature and PMV index on PPRT house design

The primary purpose of the thermal comfort design is to reduce the indoor air temperature and PMV index. The average air temperature and PMV index incident on the selected room was obtained for three houses (existing orang asli house, government initiated house, proposed comfortable PPRT house), at 24 hour times within monthly data. Both indoor temperature and PMV index were analyzed as a function of thermal comfort housing design, for the four main cardinal house

orientations (North, South, West and East) on average DBT monthly data. The maximum peak DBT on 6 March and on 10 March achieve the minimum peak day of DBT (Fig.4.1).

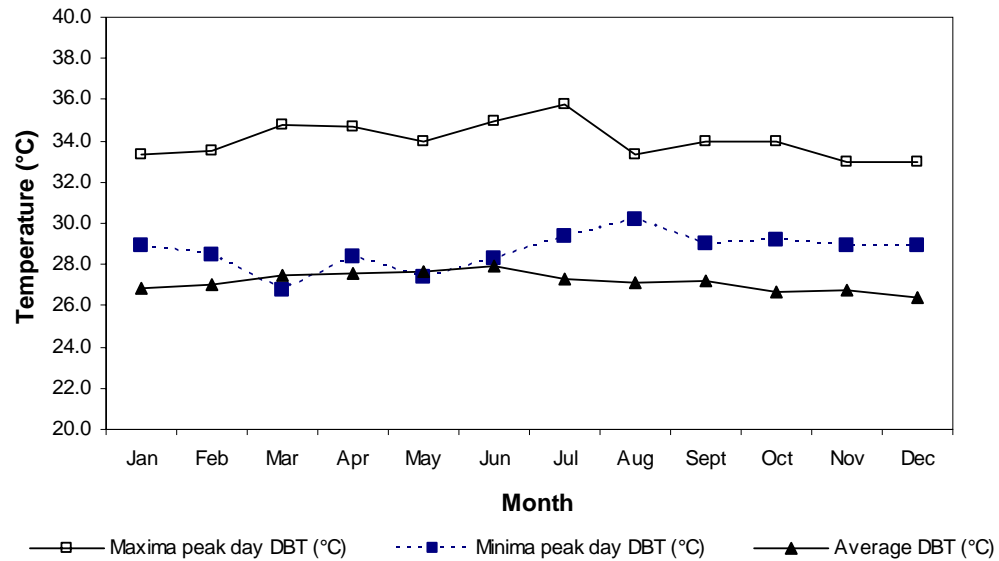


Figure 4.1: The monthly average, maximum peak day and minimum peak day of DBT

4.1.1 Existing orang asli house

The existing orang asli house model was simulated for indoor air temperature and PMV index on four cardinal orientations. The existing orang asli house has two rooms. They are living room and verandah. In the IES simulation, the house was kept empty without furniture to reduce the thermal exchange between objects. The house is without window and just has one door facing towards the front.

a. Existing orang asli house on North Orientation

The maximum indoor temperature on the north oriented house is achieved on the living room on month of June. The verandah temperature profile also indicates similar trend against the outdoor temperature. This means the indoor temperature close with outdoor temperature can be achieved by maximize opening on verandah room. Figure 4.2 illustrates that the minimum target neutral temperature (28°C) is obtained during all monthly average air temperature simulations except on month of May and June. During month of June the indoor temperature is at higher temperature and the amount of PMV is also high. Generally, there is less temperature on month of December. This can be explained that on June the north façade receive higher solar radiation than on December. But on 21 December, the façade receives lower solar radiation; therefore the temperature values are low. The maximum PMV index on month of March indicates a higher value compared to the other months (on north orientation). The profile pattern of PMV addition on the verandah had a similar pattern during all months considered. The position of the verandah is facing north. This implies that on north facing room, the impact of PMV is the main source for north hemisphere. The maximum PMV was recorded during March, April and June. Also this is clearly evident that higher PMV is received when the sun is at higher altitudes and when the solar radiation is totally induced. The PMV profile also showed a high gradient for the target PMV level than the minimum temperature. This indicates that with the increase of indoor temperature, the PMV index were added significantly compared to the maximum temperature values on month of June.

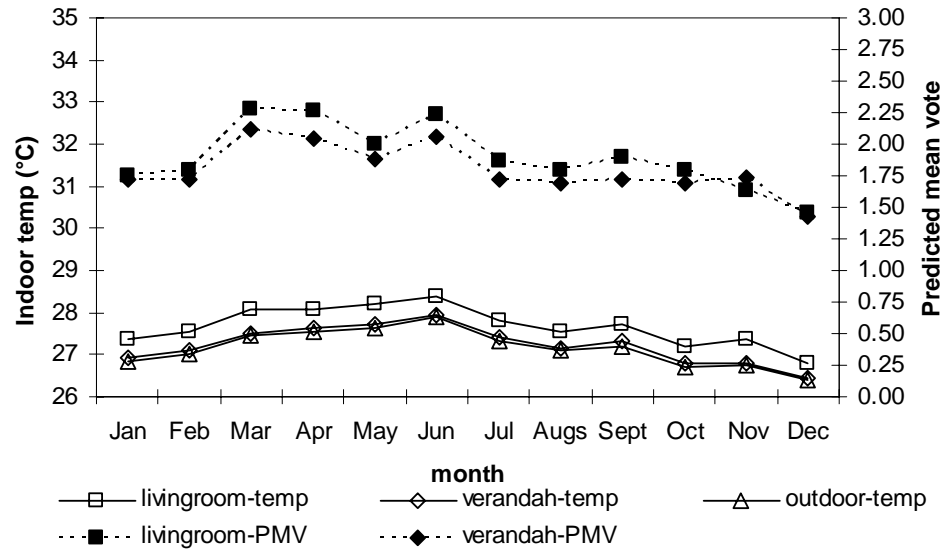


Figure 4.2: The average indoor temperature and PMV of existing orang asli house model on monthly data, north orientation

b. Existing orang asli house on South Orientation

Indoor temperature incident on the living room and verandah is evident on month of June on south oriented room façade (figure 4.3). A higher amount of indoor temperature on the living room is recorded compare to verandah. The maximum average indoor temperature (28.3°C) is above the neutral temperature. However, in month of March, it exhibits the maximum PMV values as the sun is at the equinox. The maximum PMV is 2.25 (warm). The addition pattern of the PMV had a similar profile on all months considered (figure 4.3).

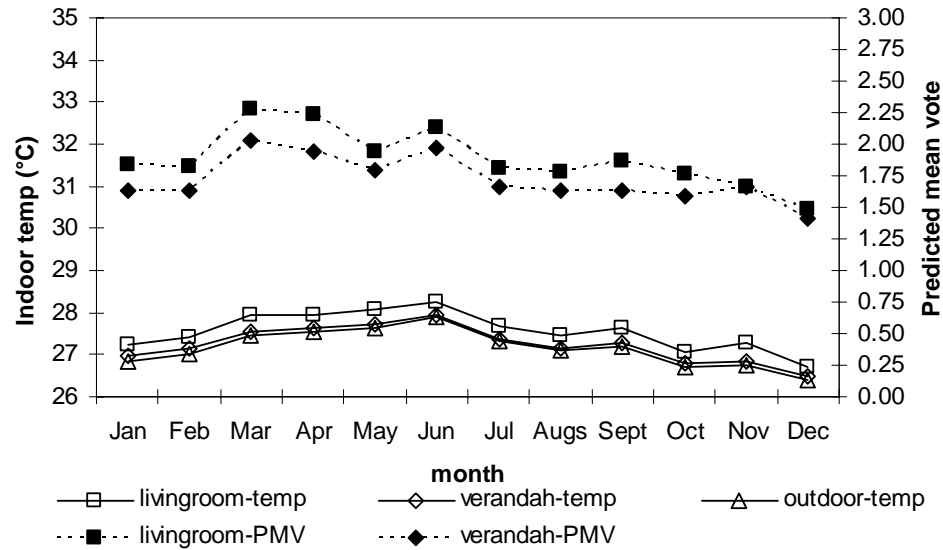


Figure 4.3: The average indoor temperature and PMV of existing orang asli house model on monthly data, south orientation

c. Existing orang asli house on East Orientation

The indoor temperature impinge is above neutral temperature on month of March until June on the aperture facing the east orientation. The temperature of the indoor room such as living room is higher than on verandah at the all times (figure.4.4). The PMV incident on living room and verandah showed a similar pattern throughout the year for each month. The PMV ranges between 1.5 until 2.25 mean that they are warm and unpleasant. This indicates design of existing orang asli house on east orientation had a more impact on increasing the PMV. The maximum PMV achieved is in month of March where the PMV is highest. However, on month of April and June, the PMV are higher than the PMV on the other months. This is because the verandah is having open window, which strongly influenced by outdoor condition.

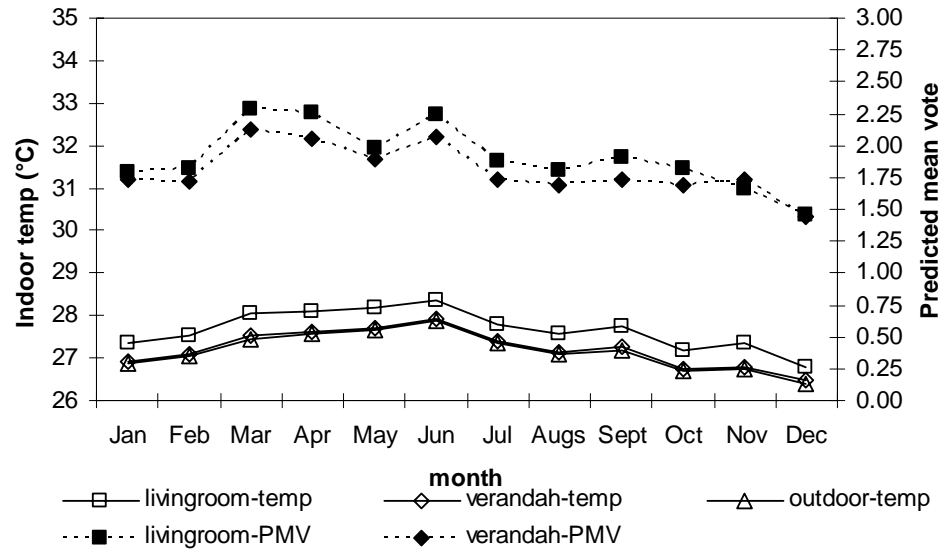


Figure 4.4: The average indoor temperature and PMV of existing orang asli house model on monthly data, east orientation

d. Existing orang asli house on West Orientation

The profile of the indoor temperature incident on the room exhibited a steep gradient on March, April and June. Hence, when the air temperature is higher value (June), the neutral temperature component is more uncomfortable **as** compared to the air temperature which is lower in value. Thus, this result in average PMV of the thermal comfort index incident on house by 1.9 (warm), on west oriented house. The profile of the PMV incident on the living room exhibited a higher gradient. During June and April, PMV incidents on all rooms are high. However, on month of March, amount of PMV incident on the room is higher. Further, on the month of December, it achieved a minimum PMV value of 1.4 (warm acceptable).

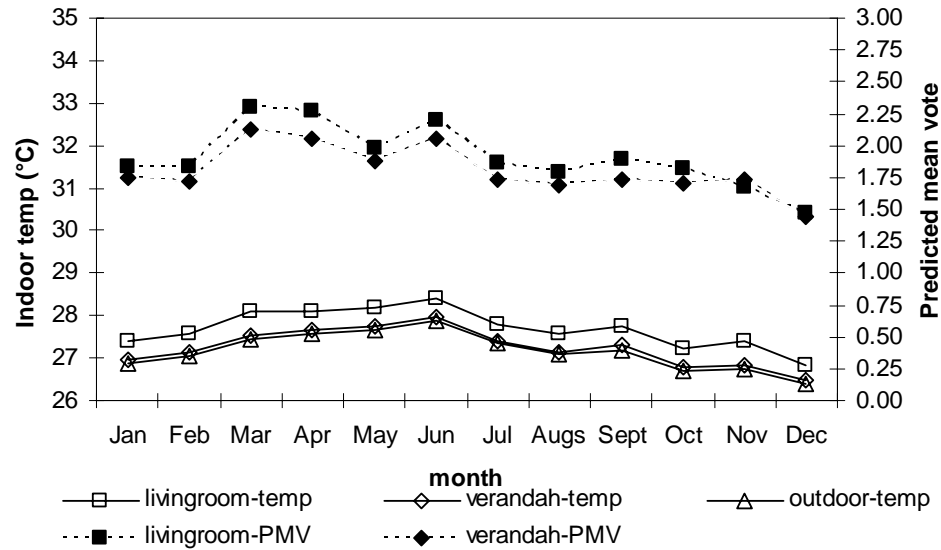


Figure 4.5: The average indoor temperature and PMV of existing orang asli house model on monthly data, west orientation

4.1.2 Government initiated PPRT

The government initiated PPRT house is tested using four models with respective cardinal orientations. Also, the house is kept empty without furniture and comprises four rooms (living room, bedroom1, bedroom2 and toilet). All rooms received ventilation with single sided openings. The windows have double sashes, which were retrofitted by the occupants. Two sashes windows (1m height, 1.5m width, and 1m above the floor) are fixed in the bedroom and living room.

a. Government initiated PPRT House on North Orientation

The fundamental principles remain the same for the temperature into the building, where the higher temperature (33.8°C) was indicated during March to April. The profile pattern of temperature is low during July to December. But on the month of September, the profile of temperature exhibited more curve than on the other six months. This is mainly due to the impact of solar path on September when solar is at

equinox. The indoor temperature of bedroom 2 is higher than the other room, and the average difference is 0.5°C . The profile pattern of PMV reduces during October to December with the decreasing of air temperature. It means during month of October to December, it is more comfortable than on month of March to June. However, the average PMV on government initiated PPRT house on north orientation is 2.25. Thus, it is between warm unpleasant until hot uncomfortable.

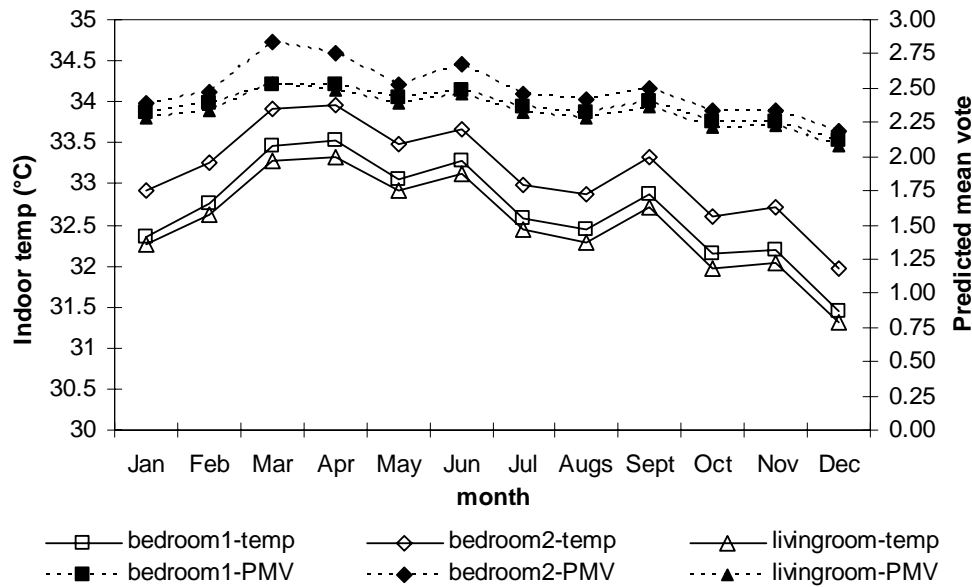


Figure 4.6: The average indoor temperature and PMV of government initiated PPRT model on monthly data, north orientation

b. Government initiated PPRT House on South Orientation

The profile pattern of indoor temperature reduction in the bedroom and living room are having similar pattern for all months. The lesser curve pattern indicated that on month of December, it had more impact in reducing the indoor temperature. In month of April, the temperature profile indicates significant increase in bedroom 2 (figure 4.7) in south orientated house. PMV on the month of March is higher and on month of December is lower. The PMV profile is similar except on month of March. Generally, the living room is more comfortable than the bedroom as shown with low PMV until 2.1 but still considers as warm condition.

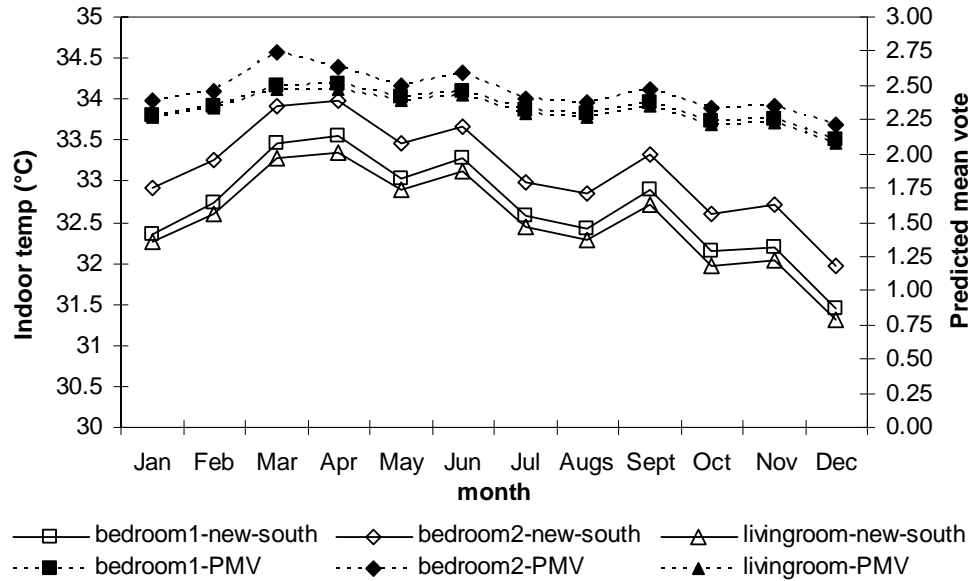


Figure 4.7: The average indoor temperature and PMV of government initiated PPRT model on monthly data, south orientation

c. Government initiated PPRT House on East Orientation

The values obtained for indoor temperature on the east orientation indicate a higher value on the month of March. The maximum and minimum temperature values obtained on bedroom 2 and living room are 34°C and 31.4°C for east orientation. The profile of the PMV into the space indicates a reduction when the temperature is decreased between on the month of April to December. For PMV comparison, the maximum and minimum values of PMV indicate 2.7 (hot uncomfortable) on March and 2.15 (warm) on December. However, the profile gradient is high (2.25) on all rooms and monthly conditions, which clearly indicates that the government initiated PPRT house is uncomfortable for the east orientation.

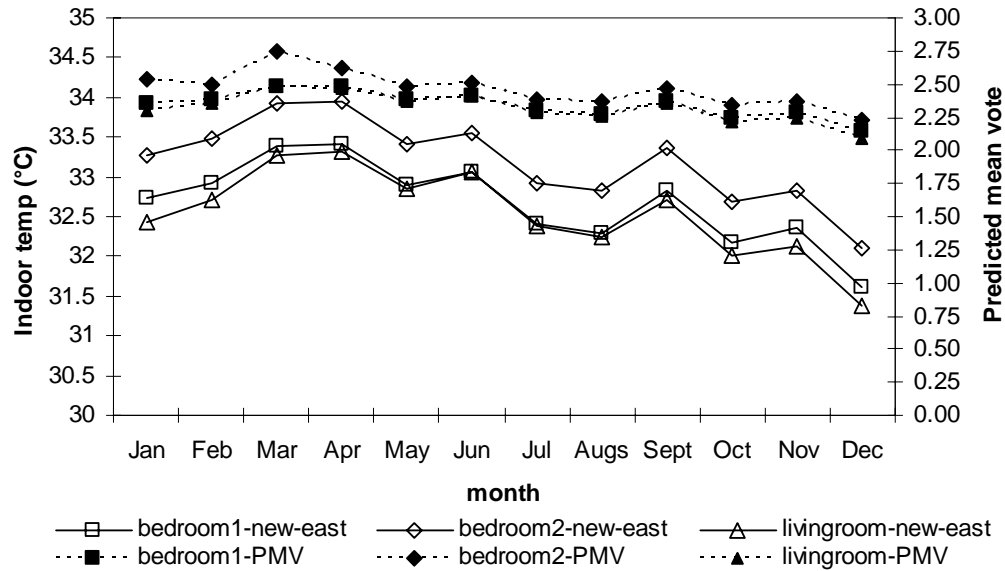


Figure 4.8: The average indoor temperature and PMV of government initiated PPRT model on monthly data, east orientation

d. Government initiated PPRT House on West Orientation

The values obtained for indoor temperature on the west orientation indicate a higher temperature (34°C) on month of April and June. The profile of the temperature into the space indicated a reduction for living room and on month of December. The maximum and minimum temperature values obtained on bare room were 34°C and 31°C for west orientation. However, the PMV profile gradient is high on the month of March and June, which clearly indicates the impact of indoor temperature on the PMV of the room for the west oriented house. The maximum and minimum values of PMV indicated as 2.75 (hot uncomfortable) and 2.1 (warm), on the west orientation.

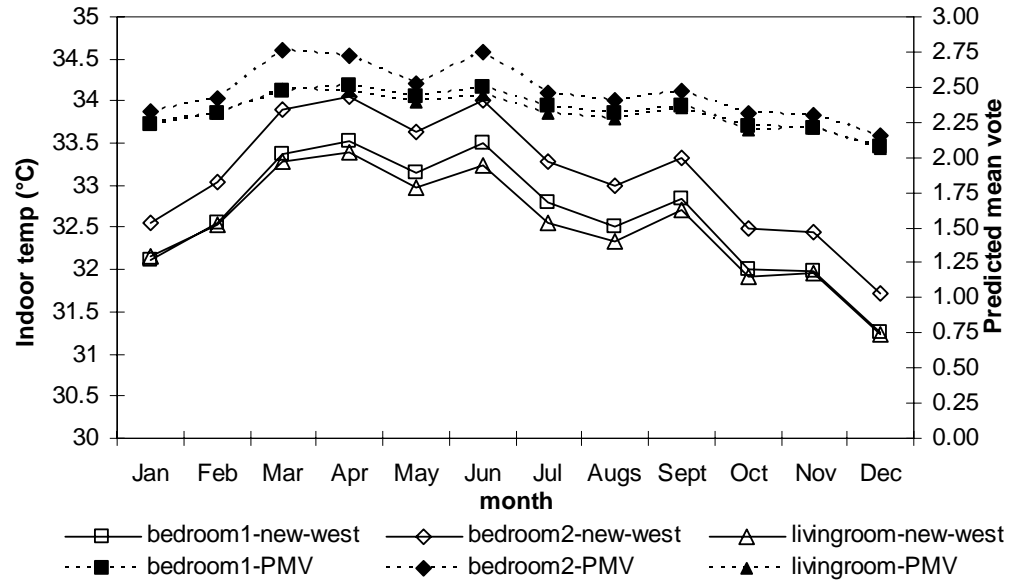


Figure 4.9: The average indoor temperature and PMV of government initiated PPRT model on monthly data, west orientation

4.1.3 Proposed comfortable PPRT

The proposed comfortable PPRT house is modified to reduce the temperature into the building. The house has six rooms (living room, 3 bedroom, kitchen and toilet). The air temperature and PMV index were calculated for the correspondence orientations and annual monthly data. The reference rooms selected were living room, bedroom1 and bedroom2. The evaluation of air temperature is based on the target neutral temperature and PMV value for comfort based on thermal index. The correspondence outdoor temperature was also presented for better understanding of the relationship between the indoor and outdoor temperature. On proposed comfortable PPRT house, each room have open-able window.

a. Proposed comfortable PPRT House on North Orientation

Figures 4.10 illustrates that the maximum indoor temperature are obtained on month of June, when the building is facing towards the north. However, on month of

December, average indoor temperature indicated a lowest value. This can be explained that in June, the north façade receives higher solar radiation. But on month of December, the façade receives lower solar radiation (in south hemisphere); therefore the temperature values are low. This indicates, with the increase of indoor temperature, the target neutral temperature levels were not achieved compared to the minimum temperature values. Figure 4.10 shows the maximum and minimum mean temperature values on three respective rooms on all month, for the north oriented house. Temperature in bedroom and living room increased to maximum temperature by 0.2°C on month of June. The PMV profile also showed a high gradient for the target thermal comfort level (0 until 1). The minimum PMV on north orientation is 1.3. It means a warm and unpleasant condition.

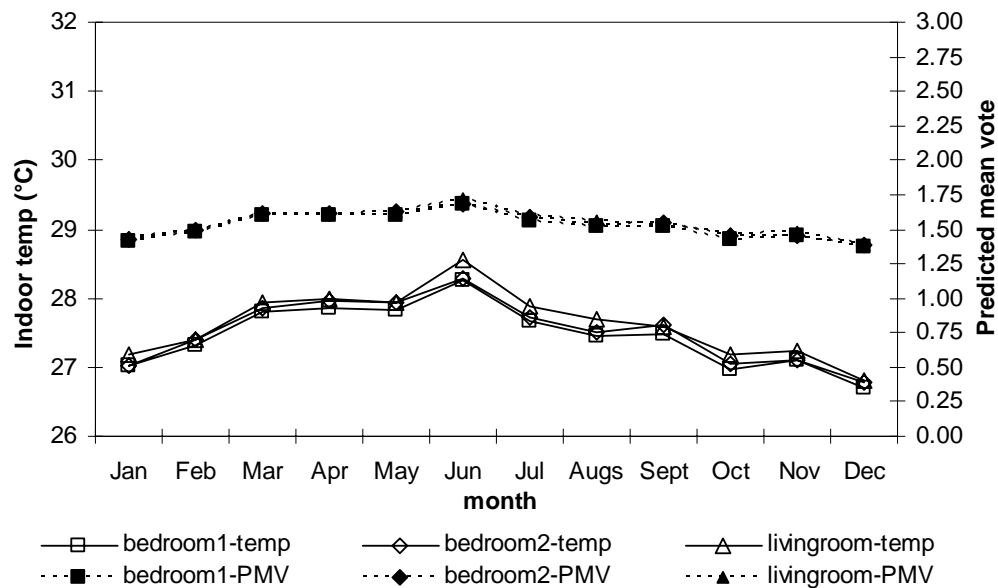


Figure 4.10: The average indoor temperature and PMV of proposed comfortable PPRT model on monthly data, west orientation, north orientation

b. Proposed comfortable PPRT House on the South Orientation

Figure 4.11 shows that the average indoor temperature was achieved for each correspondence room and the target of neutral temperature (28°C) during all month except in month of June (28.5°C), when the proposed comfortable PPRT house is facing towards the south. The indoor bedroom temperature profile indicated lesser than the indoor temperature living room profile. Also, the profile of the living room

PMV value indicated a higher gradient than bedroom. This implies that introduction of temperature had a significant impact on optimal PMV level at reference room. However, in month of June the PMV profile showed more curved pattern than in other months. The average PMV profiles in three selected rooms had a similar pattern in reference months. The living room achieved the maximum PMV value 1.6 (warm acceptable) in month of June and the minimum PMV value 1.3 (slightly warm) in month of December.

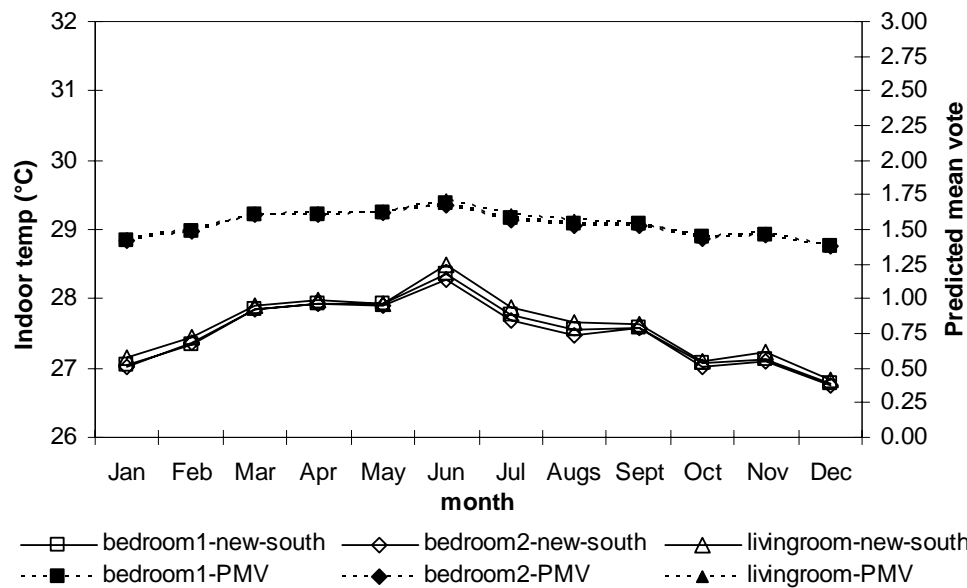


Figure 4.11: The average indoor temperature and PMV of proposed comfortable PPRT model on monthly data, west orientation, south orientation

c. Proposed comfortable PPRT House on the East Orientation

The maximum and minimum average indoor temperature was obtained in the living room and bedroom 2 in month of June and December, when the house is facing to the east. The maximum temperature (28.3°C) in month of June **was** still above the minimum target of neutral temperature. This is mainly due to the highest temperature into the building during mid year. The PMV profiles indicated a similar pattern in the bedroom and living room, which means that increase PMV cause more uncomfortable condition in the room. The comparison results between indoor temperature values and PMV showed a direct correlation between the two

components, where maximum temperature and PMV indicated similar pattern during the same month. The results indicated significant similarities between the maximum and minimum PMV values obtained in all months and rooms. The PMV was a slightly warm on month of January (minimum) and changed to a warm acceptable on month of June (maximum).

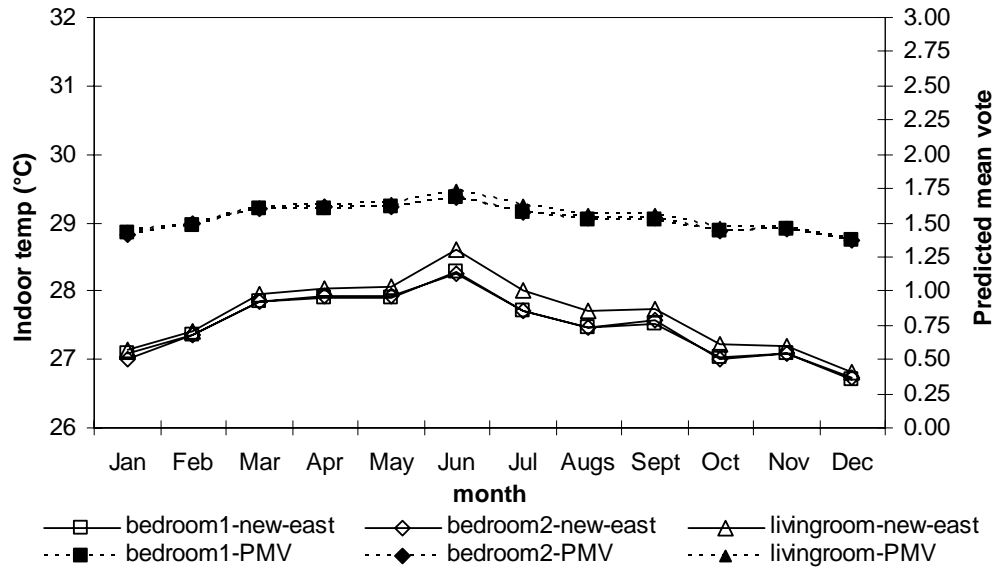


Figure 4.12: The average indoor temperature and PMV of proposed comfortable PPRT model on monthly data, east orientation

d. Proposed comfortable PPRT House on the West Orientation

The average indoor temperature of bedroom 1, bedroom2 and living room for the west oriented house are shown in figure 4.13. The maximum indoor temperature was obtained in month of June for all rooms. Results on the average temperature were obtained at similar profile of the three rooms. The results showed significant difference between average temperature values obtained in month of December (26.7°C) was less than 28.3 °C in month of June. Generally, the PMV in month of June had almost higher values in all selected rooms than in the other months. Initially, the target PMV level (0 until 1) showed sudden reduction in month of January and December and the target PMV profile had more gradient with the increase of temperature in month of June.

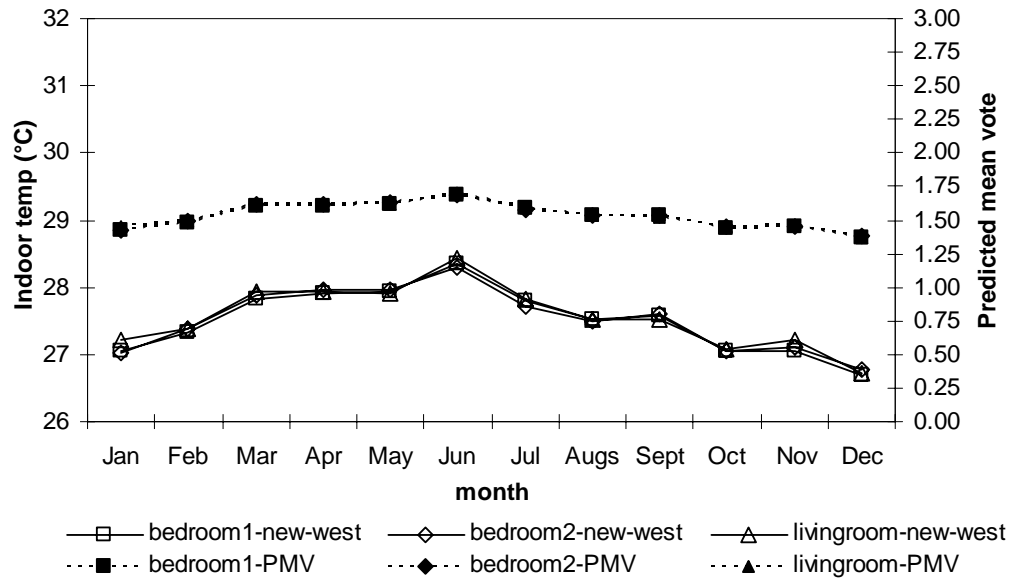


Figure 4.13: The average indoor temperature and PMV of proposed comfortable PPRT model on monthly data, west orientation

4.1.4 Thermal Comfort Condition on Hourly Data of Selected Days

The effects of hourly variations of maximum and minimum peak day on the dry bulb temperature were assessed with respect to the three houses design. This enables us to understand the condition of time component on the overall indoor temperature and PMV of the building. The analysis is done based on two days: 6 July as maximum peak day and 10 March as minimum peak day of the correspondence existing, government initiated and proposed comfortable PPRT house. The average indoor temperature and PMV were obtained for each hour on the selected days.

a. Existing orang asli house

Figure 4.14 illustrates that, significant amount of the indoor temperature was obtained in the afternoon hours between 14:00 hour and 18:00 hour for the respective

rooms. The existing orang asli house at 08:00 hour obtained average air temperature (25°C) lower than the average air temperature at 16:00 hour (34°C) of the base case room on south orientation. Based on the temperature profiles, indoor temperature of living room is higher than verandah on respective day. This affect the PMV conditions, where PMV in verandah lower than the PMV in living room. Hence, decrease of temperature resulted in a deeper gradient PMV profile pattern in verandah than in living room. The maximum and minimum PMV at 17:00 hour and 08:00 hour indicated PMV of 2.7 (hot uncomfortable) and 0.9 (slightly warm) on south orientation. On existing orang asli house, the temperature profile at afternoon hour is more than at the morning hour. The reason is that, increase of air temperature at afternoon hour in all rooms added the amount to the PMV significantly.

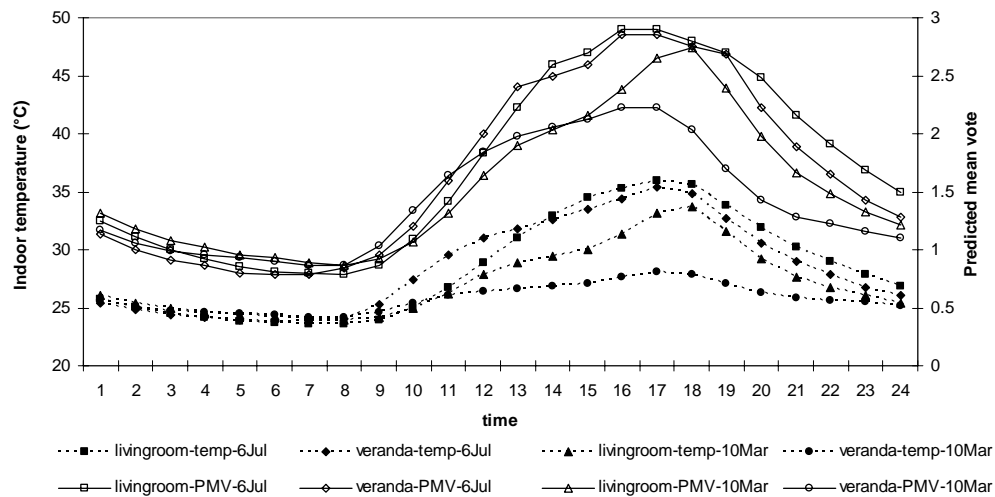


Figure 4.14: The indoor temperature and PMV for maximum (6 July) and minimum (10 March) peak day existing orang asli house on hourly data

b. Government initiated PPRT house

In this study, the indoor temperature pattern is represented by the range of the temperature between 31°C until 34.5°C which are read in three selected rooms. The figure below showed that the different times of the models influenced the air temperature pattern inside the room. The air temperature patterns seem to be affected by the time difference. Figure 4.15 shows the comparison of the average air temperature pattern of the three rooms. Air temperature pattern using simulation is

detected fluctuating at 16:00 hour until 19:00 hour is higher than 07:00 hour until 10:00 hour. For example, measurements at 16:00 hour until 19:00 hour, the air temperature could reach 2.5°C and decrease at 20:00 hour. Consequently, PMV value increases at this time and achieved its maximum at 18:00 hour. Simulation tests indicated that most of the PMV pattern within the room model was at the transition between warm (PMV value 2) at 08:00 hour to hot condition (PMV value 2.8) at 18:00 hour. The PMV inside all rooms at 18:00 hour was higher than the other times. This creates higher indoor temperature increases the PMV value inside the room and develop into an uncomfortable condition.

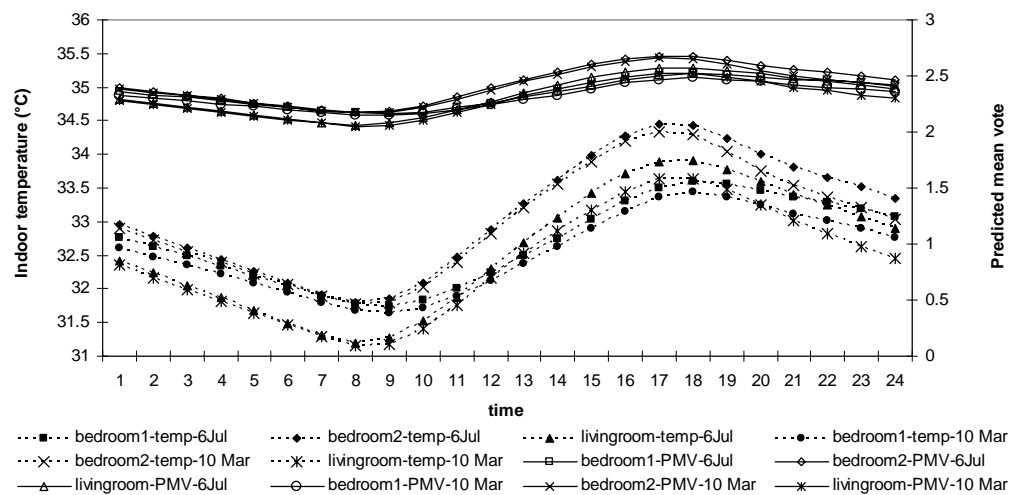


Figure 4.15: The indoor temperature and PMV for maximum (6 July) and minimum (10 March) peak day government initiated PPRT house on hourly data

c. Proposed comfortable PPRT house

Figure 4.16 shows the effect of hourly condition on the air temperature related with PMV index. It can be seen that increase in the air temperature received in the rooms caused an increase in PMV value through the system. This is to be expected, because increasing the air temperature into the room increases the PMV value. This, in turn, increases the uncomfortable condition. It can be observed from figure 4.16 that the uncomfortable thermal condition is independent of the peak air temperature time. During the mid day hours the sun is at higher altitudes and the amount of solar intensity is high. Generally, the temperature is lower in the morning

(24:00 hour to 08:00 hour). At living room area, the temperature profile showed a lesser gradient than in bedroom 2. The maximum PMV resulted 2.1 (warm) and the minimum PMV until 1.4 (warm acceptable) on selected peak DBT days.

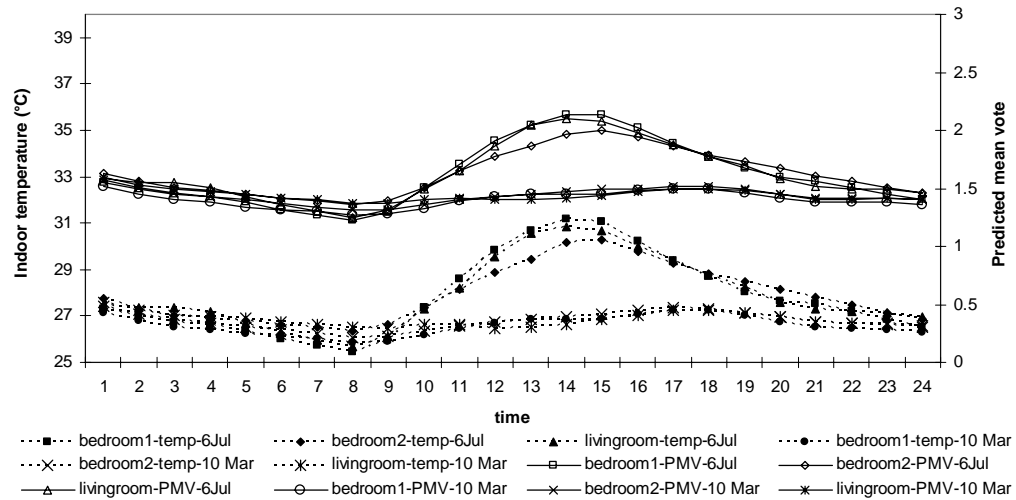


Figure 4.16: The indoor temperature and PMV for maximum (6 July) and minimum (10 March) peak day proposed comfortable PPRT house on hourly data

4.1.5 Impact of House Orientation

The air temperature and PMV index through the room are evaluated for all models on orientations and times. This enables us to understand the contribution of orientation component on the overall average indoor temperature and PMV into the building. The analysis is done based on the average value of the air temperature and PMV reduction obtained from the simulation on the existing , government initiated and proposed comfortable PPRT house.

a. Existing orang asli house

The mean reduction of indoor temperature on respective orientations showed that the south received the highest solar than east, north and west orientation. In

comparison, the south indicated more than the north in terms of temperature reduction through the living room on monthly data. On north, south and west orientation, they represent the same condition as south orientation except the reduction in air temperature pattern. The south orientation illustrated minimum air temperature. Figure 4.17 shows that the air temperature in the room, which ranged between 26.7°C and 28°C, was close to the neutral temperature. Compared to south orientation, the air temperature in the occupant zone of the other orientation was higher. Figure 4.17 shows similar PMV pattern inside the living room on north, west and east orientation. On south orientation, it represents a reduction of PMV. In general, PMV within the living room on south orientation was lower than the other orientations. The PMV contour plot indicated that the south orientation could maintain the comfortable condition within the occupant zone (compared to the other orientations).

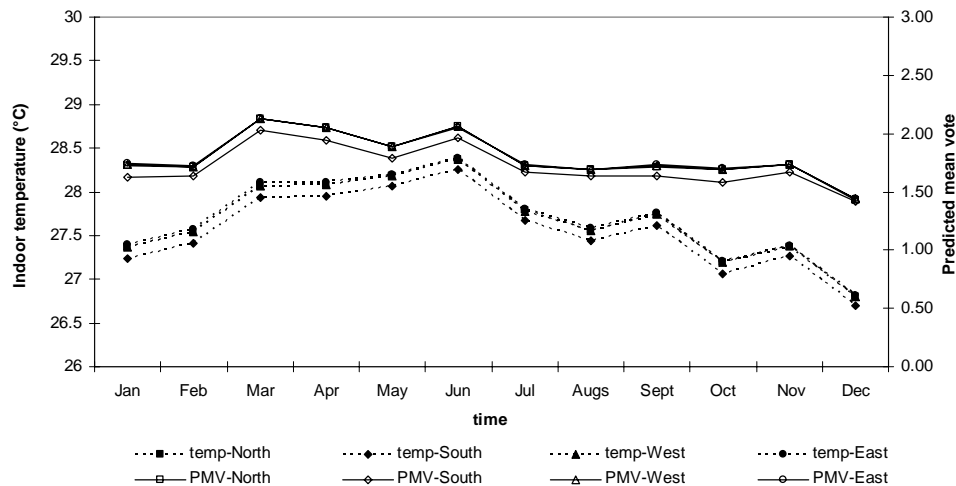


Figure 4.17: The average indoor temperature and PMV for tested correspondence existing orang asli house orientation on monthly data

b. Government initiated PPRT house

Figure 4.18 illustrates that significant amount of the indoor temperature was obtained in the living room during December and June for the respective orientations. During these months, the sun position in the south and north solstices give the significant impact of building orientation and room position of building, the

sun is beside the room pane, thus the air temperature was lower related with sun position. East and west orientation illustrated two different profiles of monthly average air temperature compared to the north and south orientations. According to figure 4.18, respective orientations obtained constant amount of air temperature for considerable month of March and September in the living room. The air temperature on east orientation increased in December. Also, this profile pattern is added on west orientation in June. Figure 4.18 illustrates the air temperature profile for the south oriented house similar with north orientation for all months. The results indicated that the peak air temperature in living room in month of December when the sun is at south solstices. Also, the air temperature is lower on east than west orientation in month of June when the sun is at north solstices and when living room is facing north orientation. The PMV profile on all respective orientation is similar. The maximum PMV (2.5) was obtained during March on north orientation. These profiles are mainly due to the effects of high air temperature. In comparison, the amount of PMV on the south and west received less than the north and east orientation.

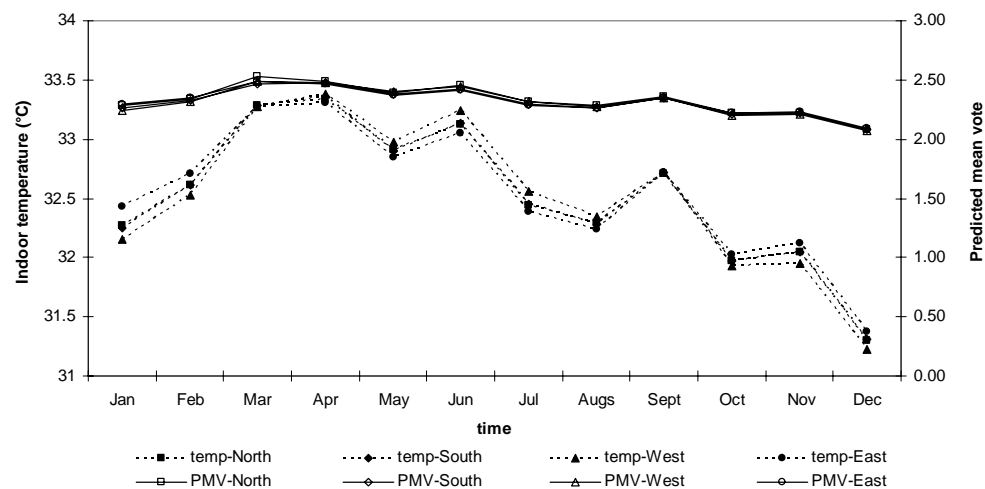


Figure 4.18: The average indoor temperature and PMV for tested correspondence government initiated PPRT house orientation on monthly data

c. Proposed comfortable PPRT house

The results showed that influence of the average air temperature is high on the east and the north orientations than the west and the south orientation incident on

the living room. Although, all orientations received similar air temperature profile into November to March compare with April to October. In comparison, east orientation indicated a higher value compared to north, south and east south orientation. However, the south orientation received lower value than north orientation but higher than east orientation for several months. This indicates that the influence of the air temperature incident in room had more effect on the house orientation in month of April to October. PMV profile showed that similar profile for all respective orientations. So, orientation is not significant impact to PMV result in proposed comfortable PPRT house.

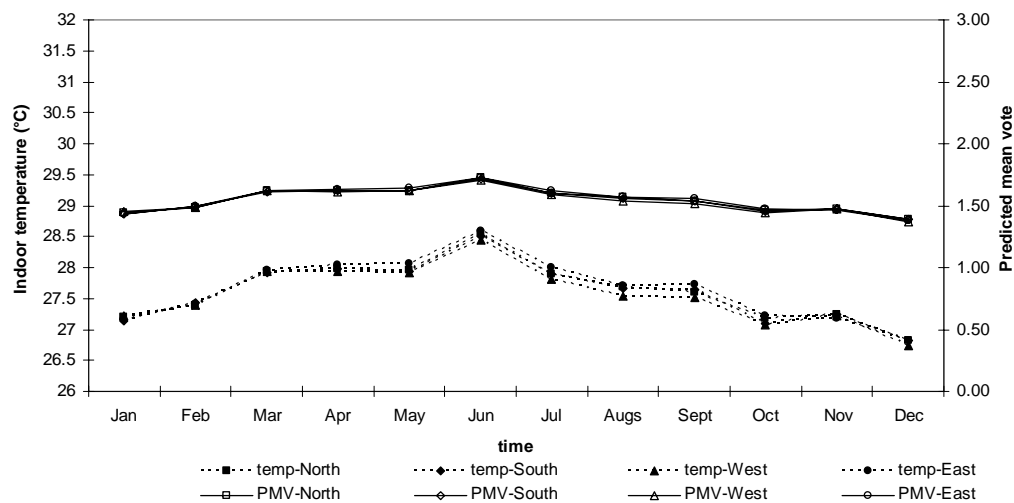


Figure 4.19: The average indoor temperature and PMV for tested correspondence proposed comfortable PPRT house orientation on monthly data

4.2 Comparison of Thermal Comfort Performance

Comparison of the average indoor temperature on three houses model indicated that proposed comfortable PPRT obtained the minimum air temperature and government initiated PPRT obtained the maximum air temperature. According to figure 4.20, the proposed comfortable PPRT achieve below target of neutral temperature for thermal comfort except at 10:00 until 18:00 on maximum peak day (6 July). The average air temperature on government initiated PPRT house indicated above of neutral temperature for all peak days. This indicates that the average air

temperature can significantly increased the PMV and the air temperature above 30°C. However, proposed comfortable PPRT house decreased the average air temperature up to 2°C on respective days. Figure 4.21 shows the average PMV values obtained in the existing, government initiated and proposed comfortable PPRT house for the south oriented house and hourly peak days. The government initiated PPRT house indicated the PMV value above comfortable condition. The PMV value range from 2 until 2.5 or the comfort condition is warm and unpleasant. At noon hour, the existing orang asli house indicated the PMV above 2, while at morning and night times showed the PMV value range between 0.75 until 1.5. The constant PMV value is found in the proposed comfortable PPRT house at hourly minimum peak day (10 March). The PMA range about 1.5. Compared with other two PPRT models, proposed comfortable PPRT house indicated lower values for day times.

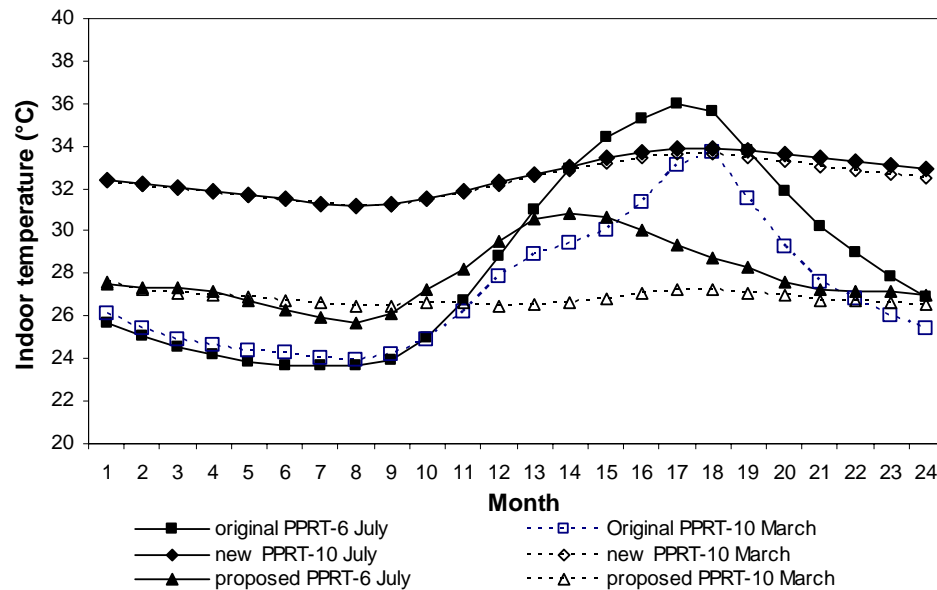


Figure 4.20: The average indoor temperature for maximum and minimum peak day dry bulb temperature of three houses design on hourly data

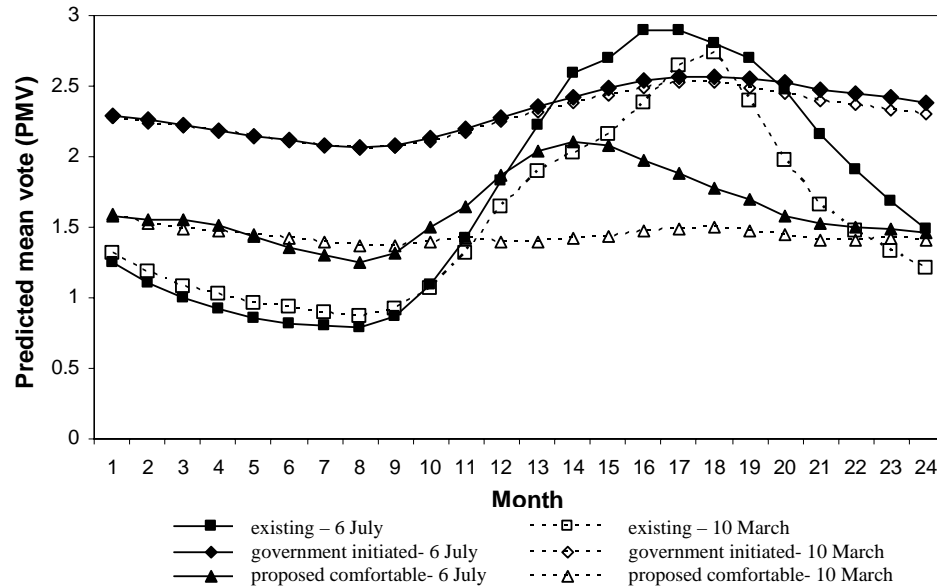


Figure 4.21: The average PMV for maximum and minimum peak day dry bulb temperature of three houses design on hourly data

Figure 4.22, shows the mean values of indoor temperature obtained for three houses model on annual monthly data. On existing and proposed comfortable PPRT houses, reference rooms experienced average air temperature that is below the neutral temperature, for all the months except in month of June. For reference room on government initiated PPRT house, the average air temperature (31°C) above the neutral temperature, for all correspondence months are found. Figure 4.23, shows the average PMV values obtained for thermal comfort index of the indoor reference PPRT house on monthly data on south and east orientations house. The correspondence average PMV were increased between 2 until 2.5 for government initiated PPRT house compared to the proposed comfortable PPRT about 1.5 (warm acceptable), while the maximum PMV value 2.1 (warm) of existing orang asli house on month of March. The average PMV value indicated 1.4 for proposed comfortable PPRT on month of January.

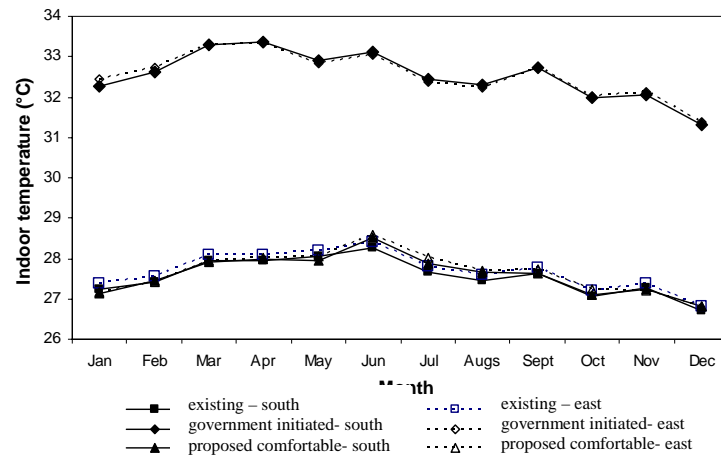


Figure 4.22: Comparison of the average temperature for tested correspondence orientation of three houses design on monthly data

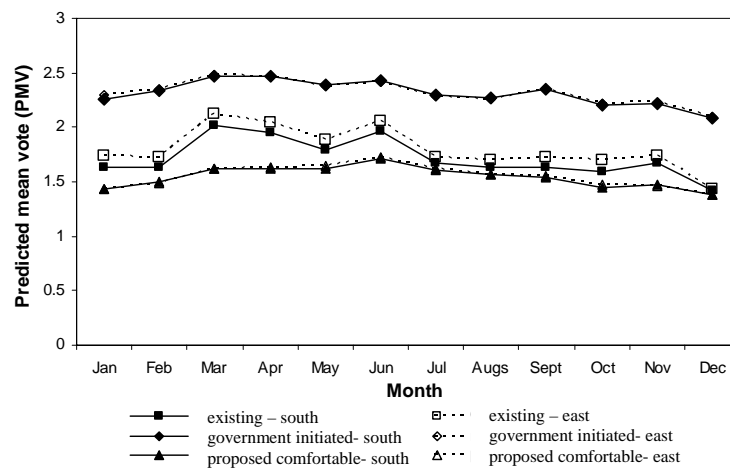


Figure 4.23: Comparison of the average PMV for tested correspondence orientation of three houses design on monthly data

4.3 Summary

The results, analysis and findings of the simulation exercise are done to determine the influence of the house design for hourly conditions and orientations in term of air temperature and PMV were presented in this chapter. The analysis of the above performance variables were carried out for the existing, government initiated and proposed comfortable PPRT model in annual monthly data for east, west, north and south orientations. The results of air temperature and PMV value were plotted

against house model and orientation in the same graph. Similarly, absolute target neutral temperature was also based against house model in the same discussion. It enabled us to understand the influence of house model on the correspondence orientations, dates and hours. The hourly average results of air temperature and PMV were also analyzed for the respective orientations. This gave overall view of the influence of different house model and orientation on the patterns of temperature and PMV value variation throughout the day. This chapter has analyzed the results obtained for the correspondence house model and house orientation for improved thermal comfort.

The proposed comfortable PPRT house provides the optimum thermal comfort. It enabled us to understand the influence of PPRT house components on the overall thermal comfort. The results showed that material and room position were main contributors on improving thermal comfort. The results revealed that the use of wall material with low U value, the use of open-able windows and walls, and south house orientation were the three important aspects towards building's thermal comfort condition.

CHAPTER 5

CONCLUSION

The findings of the research have been presented and discussed in the previous chapter. This final chapter will conclude the overall findings of the report. The application of the research findings are also discussed in relation to the aims and objectives of the report as set in Chapter 1. Finally, further work related to this study will be suggested in this chapter in order to strengthen and compliment this report.

5.1 Review of Study Objectives and Research Questions

As stated in Chapter 1, the main aim of this study is to assess and compare the comfortable housing model for the goverment initiated PPRT house design for orang asli. This objective was achieved by using the IES 5.6 Integrated Environment Solution computer simulation program. Other specific objectives of the study are as follows:

- To evaluate thermal comfort performance in PPRT house
- To develop thermal comfort design for PPRT house

The hypothesis of the study is that “appropriate” design of PPRT house model for orang asli will achieve the following:

- Decrease temperature inside house or similar with outdoor climate condition.
- Provide optimum PMV within the range of the thermal comfort requirement (0 until 1).

The term “appropriate” refers to the best performance of house model which will achieve lower air temperature and PMV index inside the house in order to obtain comfortable house.

The following questions are addressed in this study:

1. Is the the existing orang asli house model comfortable in Malaysian climatic condition?
2. Is the the goverment initiated PPRT house model comfortable in Malaysian climatic condition?
3. Which house models obtain better thermal comfort condition in Malaysia in relation with climate condition elements?
4. Does the the proposed comfortable PPRT house at (Q3) effective to increase thermal comfort condition in orang asli house?
5. What is the limitation of the the proposed comfortable PPRT house model towards increasing comfortable house?

5.2 Research Conclusion

This section attempts to conclude the research by summarizing the major findings of the research and answering the research questions as stated. They are as follows:

5.2.1 Thermal Comfort Performance

- a. The air temperature in the existing house is higher compare to neutral temperature. The results were compared for all months. June received higher than other months.
- b. Influence of PMV index on the the existing orang asli house indicated that in month of March and June, significant impact on the thermal comfort are experienced than in the other months under Malaysian condition. Therefore, it is

important to consider the PMV index in existing house especially in the afternoon times with respect to outdoor conditions.

- c. Simulations of the government initiated PPRT house were developed to predict the air temperature in similar condition. Observations on the internal air temperature revealed that this house is above the neutral temperature for all respectively conditions. The investigation of the PMV index also showed that this house on all correspondence months experienced the PMV value of an uncomfortable condition. Generally, the government initiated PPRT house experienced the highest PMV induction. Increase of air temperature on the annual month data also impact the increase of PMV values of the thermal comfort.
- d. The air temperature values indicated lower value in the the proposed comfortable PPRT house compared to another house models. Considering the material attributes to develop this the proposed comfortable PPRT house; therefore the study suggest that wall material with low U value is required to achieve maximum thermal comfort.
- e. The study indicated that the the proposed comfortable PPRT house developed having main modification factors achieve the minimum PMV index. The the proposed comfortable PPRT house model performance on different conditions determined by the PMV reduction shown positive results. Hence, it can be concluded, that for a comfortable house model, the the proposed comfortable PPRT house can be used to develop the appropriate design of PPRT house model for orang asli and provide lower than neutral temperature and good PMV index.
- f. The simulation results comparing different house models indicate that the the proposed comfortable PPRT house provide internal air temperature and PMV index lower than the other models on hourly data. This is below the minimum neutral temperature for thermal comfort (which is 28°C). In the case of the the proposed comfortable PPRT house, the lowest internal air temperature of 24°C on minima peak day (10 March) was achieved.

- g. Also the results of monthly data indicated that average air temperature and PMV are lower on propose comfortable PPRT model than government initiated PPRT model for all respectively months.

5.2.2 Thermal Comfort Design

- a. Hourly data in comfort condition had more impact on the amount of the air temperature and PMV received inside the existing orang asli house. Hence, the results indicated that in the afternoon, the house has uncomfortable air temperature and PMV index.
- b. The air temperature and PMV index on government initiated PPRT house indicated maximum air temperature and PMV in the afternoon time. Differently, it experienced highest maximum air temperature and PMV compared to the other models. Influence of the afternoon time indicated an increase in air temperature and has significant impact on the uncomfortable condition.
- c. The hourly data of the the proposed comfortable PPRT house howed the maximum air temperature and PMV on different peak DBT days. Increase of air temperature on mid day until the afternoon time reduced the air temperature and PMV. The constant air temperature obtained contributes to effective comfortable condition on minima peak DBT day.
- d. Simulation of the existing house on the south orientation resulted in better air temperature performance than on the north, south, east and west orientations. This implies that decreasing air temperature had an impact to PMV index reduction. These results can be combined to obtain the optimum thermal comfort house model.

- e. The uncomfortable condition on government initiated PPRT house was obtained on the east orientation. It showed the highest air temperature and PMV index. This indicates that when considering only the indoor air temperature and PMV index, the east orientation can become thermally uncomfortable.
- f. The relationship between the thermal comfort and the the proposed comfortable PPRT house orientation were determined based on the assumptions of the air temperature and PMV reduction on the selected orientation. The optimum orientation suggested that the maximum temperature and PMV reduction can be achieved on south orientations

5.3 Suggestions for Further Research

This research has revealed two significant findings. Firstly, the introduction of the proposed comfortable PPRT house is significantly produced thermally comfortable house. It can maintain the preferable air temperature and PMV index required for thermal comfort (below 28°C and PMV index 1) in all selected rooms. Secondly, the existing orang asli and government initiated PPRT house (similar cases for PPRT house in the planning guideline) experienced minimum thermal comfort inside the rooms. As a result the internal thermal comfort performance of the government initiated PPRT house produce warm and hot condition. Some of the area even achieved air temperature above 31°C and 2.5 of PMV index. However, the introduction of the proposed comfortable PPRT house material and window opening at the proposed comfortable PPRT house increases and further improve the thermal comfort condition.

This study has suggested that how a simple PPRT house strategy can be effectively used to reduce the air temperature and increase comfortable condition. The the proposed comfortable PPRT house design strategies require simple and rational modifications in material of the wall and window openings. However, several areas of study need further investigation, to develop the knowledge of the

proposed comfortable PPRT house strategies in Malaysia and regions with design of similar climates. Therefore, it is recommended that future research could look further into this area in order to strengthen and compliment this research.

The following are some suggestions:

- a. Investigation on the effectiveness of the wall material. Apart from lower U value of wall material, the other factors need to be investigated are; the combining between several local material.
- b. Further investigations are required to determine the effects of the the proposed comfortable PPRT house strategy on different room size on various building forms.
- c. Further studies need to be carried out to develop a method to define housing design by considering the total heat transfer. In hot and humid tropics influence of heat gain on thermal effects are significant. Therefore, considering the total heat transfer may be an important aspect in determining different thermal comfort strategies. Studies on heat transfer properties can be used to develop a design method to determine different comfortable housing strategies for the tropics.
- d. Further study and analysis on existing orang asli and government initiated PPRT house typology should be carried out to give a better indication on the indoor thermal comfort performance. Hence, a better comparison on the performance can be carried out.

Finally, it can be acknowledged that this work is a small contribution by the researcher towards providing comfortable and healthy PPRT house for the hardcore poor. It is hoped that it can induce good design solution that is not impossible in term of its low cost towards providing better comfort and more beneficial to the user.

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APPENDIX A

**Comfortable Housing Model in PPRT House For Orang Asli in Malaysia
Inatex 2007 Poster**



INTRODUCTION

This prototype model house is about thermally comfortable housing model for orang asli in Malaysia. It is an alternative to the government initiated designed under JHEOA (The Government implemented specific development programmes for the indigenous community, the Orang Asli, which included economic and social programmes that improved their standard of living by a special programme called the Hard-core Poor Development Programme or PPRT).

ISSUE

The PPRT house developed by the government is not only small but has heat-trapping concrete walls and heat-radiating zinc roofs. This house indicated an uncomfortable indoor condition if compared to the original or existing orang asli house. This is due to the architectural design solutions that do not permit good passive cooling strategy for achieving thermal comfort. This can be illustrated by high indoor temperature experienced indoor in the government initiated PPRT house (under JHEOA) during day time (through indoor comfort computer simulation study).

PROPOSITION

The New Alternative Proposal for PPRT house is designed by adopting traditional orang asli house elements as possible alternative techniques used for passive cooling strategies, and also embracing and maintaining their lifestyle. The construction uses light modular construction technique of mostly timber post and beam and flush door panels for the house

OUTCOME

When similar indoor comfort computer simulation study was performed. The proposed PPRT house showed that it achieved good thermal comfort performance with reduce air temperature (until 2°C) and PMV index (until 1). The other significant factor is that it can continuously maintain comfortable indoor condition even in mid day and regardless of the outside climate condition. This effect is important toward improving the thermal comfort performance in the PPRT house for orang asli through the use of passive cooling design strategy.



Existing House



Existing House



Government Initiated House



Government Initiated House



New Alternative Prototype House



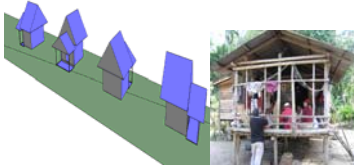
New Alternative Comfortable House Model for PPRT

Principal Researcher: Assoc. Prof. Dr. Mohd Hamdan bin Ahmad, Researcher: Assoc. Prof. Dr. Mohd Zin bin Kandar, Roshida Abd Majid, Research Assistant: Halimah Yahya & Agung Murti Nugroho
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METHODOLOGY

DEVELOPMENT OF SIMPLIFIED PPRT MODEL



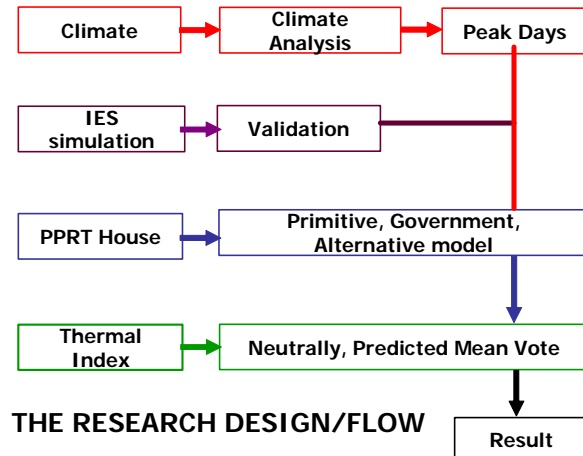
The Primitive House Simulation Model



The Government PPRT House Simulation Model

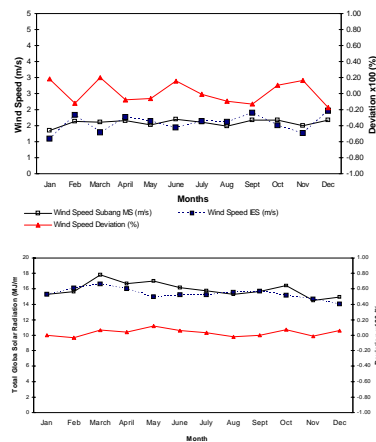


The Proposed New alternative PPRT House Simulation Model

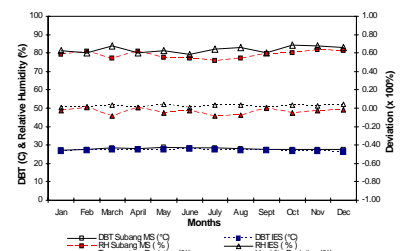


THE RESEARCH DESIGN/FLOW

CLIMATE DATA



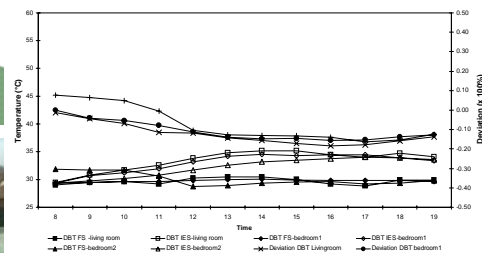
Comparison of the monthly data between IES Kuala Lumpur and Subang Meteorological Station weather file data (2000-2003) for wind speed (Latitude: 3.120, Longitude: +101.550 & Time zone: +7)



Comparison of the IES Kuala Lumpur weather data with Subang Meteorological Station weather file data (2000-2003) for dry bulb temperature and relative humidity (Latitude: 3.120, Longitude: +101.550 & Time zone: +7)

THE VALIDATION STUDY

Model	Element	Material	Thickness (m)	U value (W/m²K)
Original 1967	Roof	Zink	0.05	3.5
	Ceiling	-	-	-
	External Wall	Timber (bark)	0.2	2.2
	Internal Wall	-	-	-
	Floor	Stone, cast concrete	0.1	0.5315
New 1967	Window	wood	0.1	0.3488
	Door	Asbestos Cement Decking	0.15	4.6
	Ceiling	Gypsum plastering	0.1	2.0696
	External Wall	brickwork	0.22	4.5
	Internal Wall	brickwork	0.22	4.5
Proposed 2007	Floor	London clay, stone, cast concrete	0.2	0.800
	Window	Single Glass	0.1	2.448
	Door	Wood	0.15	0.3488
	Roof	Asbestos Cement Sheet	0.1	2.1
	Ceiling	-	-	-
Proposed 2007	External Wall	plywood	0.1	0.5699
	Internal Wall	plywood	0.1	0.5699
	Floor	London clay, stone, cast concrete	0.1	0.800
	Window	-	-	-
	Door	Wood	0.1	0.3488



Comparison of the dry bulb temperature result between field measurement and IES simulation

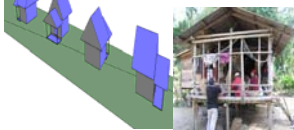


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SIMULATION RESULT



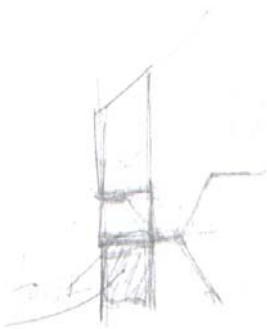
The Primitive House Simulation Model



The Government PPRT House Simulation Model

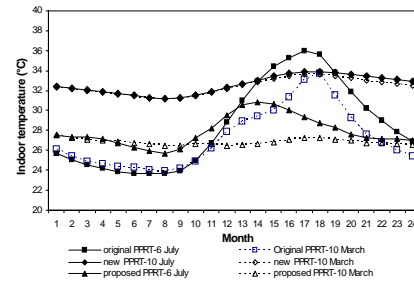


The Proposed New alternative PPRT House Simulation Model



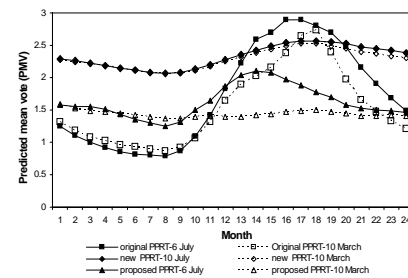
COMPARISON OF THERMAL COMFORT PERFORMANCE

The average indoor temperature for maxima and minima peak day dry bulb temperature of three PPRT house design on hourly data



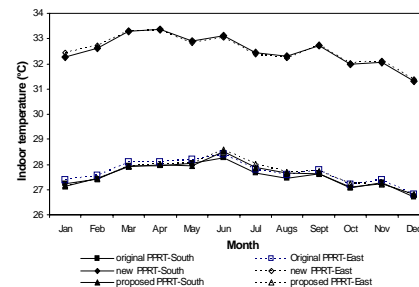
COMPARISON OF THERMAL COMFORT PERFORMANCE

The average PMV for maxima and minima peak day dry bulb temperature of three PPRT house design on hourly data



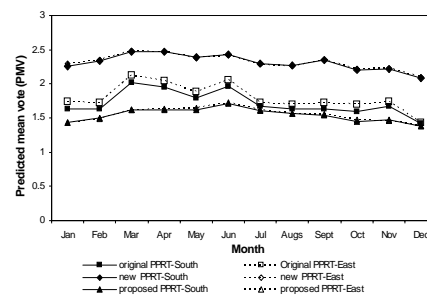
COMPARISON OF THERMAL COMFORT PERFORMANCE

Comparison of the average temperature for tested correspondence orientation of three PPRT house design on monthly data



COMPARISON OF THERMAL COMFORT INDEX

Comparison of the average PMV for tested correspondence orientation of three PPRT house design on monthly data

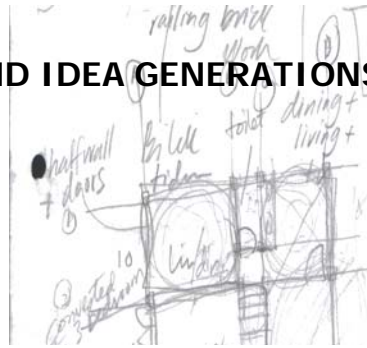


New Alternative Comfortable House Model for PPRT

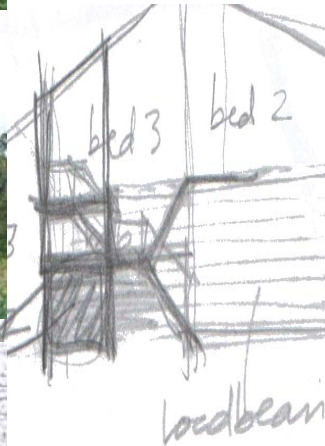
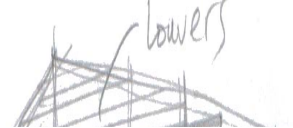
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DESIGN PROCESS AND IDEA GENERATIONS



IDEA FROM GLENN MURCUTT



FINAL DESIGN



IDEA FROM EXISTING DWELLINGS



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FINAL DESIGN



SHORT SECTION



FLOOR PLAN



FRONT VIEW



LONG SECTION



SIDE VIEW



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